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ESTONIAN AND FINNISH GRADUATING SENIORS' OPINIONS AND MOTIVATION ABOUT PHYSICAL EDUCATION

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ABSTRACT

This study investigated the general feelings and opinions about their health, school, leisure time physical activity and physical education among senior graduating students in Estonia and Finnish. The results showed that Estonian and Finnish youth had similar opinions about their health and the similar patterns in leisure time physical activity.

Many of the Finnish and Estonian graduating senior reported that there is something that bothers in PE classes (PE classes are boring, condition, evaluation system). Finnish and Estonians students reported that evaluation is based on too much performing of general standards although evaluation should measure more individual development and how individual pushes during the PE classes. Most of the Estonian students reported that conditions during and especially after PE classes needed improvements. The study demonstrated that Finnish boys were more interested in having more PE in schools than Estonian boys. However most of the Estonian graduating students reported that there should be more optional PE lessons for choosing in schools.

Additionally, in terms of motivation in physical education, the study revealed that the external type of motivation among Estonian girls was significantly higher compared to Finnish girls.

Key words: health, leisure time physical activity, intrinsic and extrinsic motivation, physical education.

INTRODUCTION

Physical education (PE) is being viewed as an important means in promoting health and wellness that may, in turn, influence students to lead physically active lifestyles. Attitudes toward physical activity and perceptions about physical education classes are important to understand as they can influence an individual's decision to begin or to continue participation in an activity [1]. A thorough understanding about students' attitude towards physical activity will give an impact on the effectiveness of teachers and the planning of programs that cater for student needs in order to ensure the achievement of predetermined objectives and aims [13]. Furthermore, research in this area identifies curriculum content, classroom environment, and teacher behavior as the primary determinants of negative and positive attitudes toward physical education [4].

Children and youth must learn healthful living habits while in school because many will not attend college or be able to afford fitness club memberships or expensive exercise equipments. Through participation in sports, students can develop positive personal traits, such as self-confidence and discipline, and social skills, such as teamwork and sportsmanship [11].

There are several problems and open questions when discussing about the connection between the physical activity and the school physical education. What is clear is that present policies and approaches in physical education curricula do not seem to be having a positive impact with regard to facilitating the adoption of an active lifestyle. Because of this, it is important to explore ways to use physical education to increase physical activity and promote healthy lifestyles [5].

Research's has consistently demonstrated that enjoyment represents a key factor underlying the motivation for children and youth to maintain positive engagement in both physical activity and PE. In relation to school physical education, enjoyment represents a direct and tangible influence on students' participatory behavior, providing immediate reward for being physically active. It is important, therefore, for researchers to acquire a clearer understanding of the motivational mechanisms that underlie the positive or negative affective outcomes of PE, such as enjoyment or anxiety [17].

The purpose of this study was to investigate general feelings and opinions about health, leisure time physical activity and physical education, as well as motivation in physical education among senior graduating students in Estonia and Finnish.

Research is needed because this kind of knowledge could be useful for making PE classes more attractive and effective for school-aged Estonian and Finnish youth.

METHODS AND PROCEDURES

Participants and procedures

Participants were 269 graduating seniors (140 Estonians and 129 Finnish) from 8 different high schools in Tartu (Estonia) and Tampere, Nokia (Finland) (Table 1). Permission to carry out the questionnaire in each school was obtained from the administration, headmaster and the physical education teachers. The anonymous questionnaire was administered in the classrooms. The purpose of the study was explained and the instructions were given for completing the questionnaire. It was emphasized that the questionnaire was designed to measure students' general feelings and opinions about PE classes.

Table 1.The anthropometrics results of Estonian (n=140) and Finnish (n=123) graduating seniors.

Group	n	Height (cm)		Weight (kg)	
		mean	SD	mean	SD
Estonian boys	79	183.2	5.5	75.6	13.4
Finnish boys	70	179.5	6.3	73.5	9.8
Estonian girls	61	169.3	5.4	59.0	7.3
Finnish girls	53	166.6	5.1	58.0	10.2

MEASURES

The questionnaire was divided into two parts. The first part of the questionnaire, compiled by the authors of this study, examined students' general feelings and opinions about their health, studies in school, leisure time physical activity and physical education. Second part of the questionnaire examined students´ motivation in physical education. The Sport Motivation Scale (SMS), developed by Pelletier et al., [14], which has been adapted to physical education and translated into Estonian by Hein and colleagues [8] and into Finnish by Jaakkola [9], was used. The SMS consisted of 28 items examining participants' motivation with three types of intrinsic motivation (intrinsic motivation to know, to accomplish, and to experience), three types of extrinsic motivation (identified, introjected, and external regulation) and amotivation. Since these three types of intrinsic motivation have shown to be strongly correlated [10], the averaged scores of three types of intrinsic motivation were used to characterize a global intrinsic motivation variable. Also, averaged scores of three types of extrinsic motivation were used in this study to characterize a global extrinsic motivation variable. Students responded to the items on a 7-point scale ranging from 1 = totally agree to 7 = totally disagree.

Statistical analysis

The data was analyzed using statistical package of SPSS 17.0. The cross tabulation analysis was used to examine the distribution of responses to the items asking students' opinions about their health, school, leisure time physical activity, and physical education. The chi-square statistics was utilized to determine whether the differences in distribution of responses were statistically significant. In order to determine differences in students' motivation in physical education, independent samples t-test was used.

In this study the focus was on determining the possible national differences between Estonian and Finnish senior graduating students. Specifically differences between Estonian and Finnish male senior graduating students, as well as Estonian and Finnish female senior graduating students were determined. Statistical significance was set at $p<0.05$.

RESULTS

Graduating seniors' opinions about their health and physical activity

Results revealed that 35.4% of Estonian boys and 33.8% of Finnish boys valued their health as *very good.* 53.2% of Estonian boys and 56.3% of Finnish boys valued their health as *good.* 11.4% of Estonian boys and 9.9% of Finnish boys valued their health as *moderate.* None of Estonian or Finnish boys valued their health as *poor.* Differences between Estonian and Finnish boys were not statistically significant: χ^2 (2, n=150)=0.180, p>0.05.

As for girls, results revealed that 23.0% of Estonian girls and 8.6% of Finnish girls valued their health as *very good.* 60.7% of Estonian girls and 77.6% of Finnish girls valued their health as *good.* 16.4% of Estonian girls and 13.8% of Finnish girls valued their health as *moderate.* None of Estonian or Finnish girls valued their health as *poor.* Differences between Estonian and Finnish girls were not statistically significant: χ^2 (2, n=119)=5.194, p>0.05.

In terms of physical fitness, results revealed that 16.5% of Estonian boys and 19.7% of Finnish boys valued their physical fitness as *very good.* 43.0% of Estonian boys and 43.7% of Finnish boys valued their physical fitness as *good.* 38.0% of Estonian boys and 29.6% of Finnish boys valued their physical fitness as *moderate* and 2.5% of Estonian boys and 7.0% of Finnish boys valued their physical fitness as *poor.* Chi-square test revealed that the percentage of these answers were not statistically significantly different among Estonian and Finnish boys: χ^2 (3, n=150)=2.630, p>0.05.

As for girls, results revealed that 9.8% of Estonians and 5.2% of Finnish students valued their physical fitness as *very good.* 63.9% of Estonian girls and 50.0% of Finnish girls valued their physical fitness as *good.* 23.0% of Estonian girls and 41.4% of Finnish girls valued their physical fitness as *moderate* and 3.3% of Estonian girls and 3.4% of Finnish girls valued their physical fitness as *poor.* The percentages of these answers were not statistically significantly different among Estonian and Finnish girls: χ^2 (3, n=119)=5.030, p>0.05.

In terms of physical activity, results revealed that 17.7% of Estonian boys and 15.7% of Finnish boys were physically active more than four times a week. 21.5% of Estonian boys and 31.4% of Finnish boys were physically active three to four times a week. 39.2% of Estonian boys and 24.3% of Finnish boys were physically active one or two time a week. 16.5% of Estonian boys and 24.3% of Finnish boys were physically active less than once a week. 5.1% of Estonian boys and 4.3% of Finnish boys reported that they are not physically active. Differences between the Estonian and Finnish boys were not statistically significant: χ^2 (4, n=149)=5.236, p>0.05.

For girls the results revealed that, 9.8% of Estonian girls and 19.0% of Finnish girls were physically active more than four times a week. 24.6% of Estonian girls and 24.1% of Finnish girls were physically active three to four times a week. 32.8 % of Estonian girls and 34.5% of Finnish girls were physically active one or two times a week. 27.9% of Estonian girls and 19.0% of Finnish girls were physically active less than once a week. 4.9% of Estonian girls and 3.4% of Finnish girls reported that they are not physically active. Differences between the Estonian and Finnish girls were not statistically significant: χ^2 (4, n=149)=2.917, p>0.05.

Next the students were asked to indicate how many hours per week they are physically active on leisure time that causes sweating. Results showed that 21.5% of Estonian boys and 18.8% of Finnish boys were physically active more than five hours per week. 8.9% of Estonian boys and 13.0% of Finnish boys were physically active four or five hours per week. 22.8% of Estonian boys and 21.7% of Finnish boys were physically active three to four hours per week. 38.0% of Estonian boys and 29.0% of Finnish boys were physically active approximately one hour per week. 8.9% of Estonian boys and 17.4% of Finnish boys reported that they are not physically active at all. Differences between the Estonian and Finnish boys were not statistically significant: χ^2 (4, n=148)=3.713, p>0.05.

As for girls, 11.5% of Estonian girls and 12.1% of Finnish girls were physically active on leisure time that causes sweating more than five hours per week. 6.6% of Estonian girls and 3.4% of Finnish girls were physically active four to five hours per week. 23.0% of Estonian girls and 24.1% of Finnish girls were physically active three or four hours a week. 36.1% of Estonian girls and 41.4% of Finnish girls were physically active approximately one hour per week. 23.0% of Estonian girls and 19.0% of Finnish girls reported that they are not physically active at all. Differences between the Estonian and Finnish girls were not statistically significant: χ^2 (4, n=119)=1.039, p>0.05.

Students were also asked to indicate where they exercise in their leisure time. Results indicated that 35.4% of Estonian boys and 37.7% of Estonian girls reported that training in sport clubs is the most popular way of doing sports after school. 38.6% of Finnish boys and 51.7% of Finnish girls were training most often with the friends without coaching. Differences between the Estonian and the Finnish boys were not statistically significant: χ^2 (4, n=148)=3.713, p>0.05. However Chi-square test revealed that the percentage of answers was statistically significant between Estonian and Finnish girls: χ^2 (5, n=119)=11.381, p<0.05.

Graduating seniors' opinions about physical education

Students were asked to indicate whether they like PE lessons. Results revealed that, 84.8% of Estonian boys and 84.3% of Finnish boys liked PE lessons (χ^2 (1, n=149)=0.008, p>0.05). For girls, 75.4% of Estonian girls and 71.9% of Finnish girls liked PE lessons (χ^2 (1, n= 18)=0.182, p>0.05).

Students were next asked to indicate whether they consider PE lessons as interesting. Results revealed that 75.9% of Estonian boys and 81.4% of Finnish boys rated PE lessons as interesting. (χ^2 (1, n=149)=0.661, p>0.05). For girls, 63.9% of Estonian girls and 63.8% of Finnish girls rated PE lessons as interesting (χ^2 (1, n=119) = 0.000, p>0.05).

When asked about the importance of PE, 83.3% of Estonian boys and 80.3% of Finnish boys reported PE lessons are important (χ^2 (1, n=149)=0.233, p>0.05). Answers from girls revealed that 80.3% of Estonian girls and 85.7% of Finnish girls though that PE lessons are important (χ^2 (1, n=117)=0.598, p>0.05).

When asked whether the students enjoy PE lessons results revealed that 75.6% of Estonian boys and 87.1% of Finnish boys enjoyed the PE classes (χ^2 (1, n=148)=3.182, p>0.05). For girls, the results revealed that 70.5% of Estonian girls and 77.2% of Finnish girls enjoyed the PE classes (χ^2 (1, n=118)=0.683, p>0.05).

Graduating seniors' opinions about relationships in physical education

When asked about the students' relationship with their PE teacher the results indicated that 49.4 % of Estonian boys and 57.1% of Finnish boys having very good relationship with the PE teacher. 44.3% of Estonian boys and about 38.6% of Finnish boys reported that they get well along with the PE teacher. Only 2.9% of Finnish boys and none of Estonian boys reported that they don't get along with the PE teacher (χ^2 (3, n=149)=7.362, p>0.05). As for girls, 57.7% of Estonian girls and 24.1% of Finnish girls reported that they get very well along with the PE teacher. 29.5% of Estonian girls but 72.4% of Finnish girls reported that they get well along with the PE teacher. 4.9% of Estonian girls and none of Finnish girls reported that they don't get along with the PE teacher. Chi-square test revealed that the percentage of these answers were statistically different among Estonian and Finnish girls: χ^2 (3, n=119)=22.872, p<0.05.

The results revealed that 53.2% of Estonian boys and 52.9% of Finnish boys reported that they get very well along with the classmates in PE. 46.8% of Estonian boys and 38.6% of Finnish boys reported that they get well along with the classmates in PE. Only 2.9% of Finnish boys and none of Estonian boys reported that they don't get along with the classmates in PE (χ^2 (3, n=149)=7.362, p>0.05). As for girls, 44.3 % of Estonian girls and 25.9% of Finnish girls reported that they get very well along with the classmates in PE. 52.5% of Estonian girls and 69.0% of Finnish girls reported that they get well along with the classmates in PE. 3.3% of Estonian girls and 5.2% of Finnish girls reported that they don't get along with the classmates in PE (χ^2 (2, n=119)=4.445, p>0.05).

Graduating seniors' opinions about evaluation system, provision, and conditions of physical education

When asked from Estonian and the Finnish graduating seniors if there was anything that bothers in the PE lessons, 54.4% of Estonian boys and 88.6% of Finnish boys answered *yes*. Differences between the Estonian and Finnish boys were statistically significant: χ^2 (1, n=149)=20.788, p<0.05. Similarly, 49.2% of Estonian girls and 82.8% of Finnish girls reported that there is something that bothers in the PE. Differences between the girls were statistically different: χ^2 (1, n=119)=14,844, p<0.05. The notion that "PE classes are boring" was one of the main reasons why Estonian and Finnish boys and girls reported that there is something that bothers in the PE classes (Figure 1).

The results were following when graduating seniors were asked the question *Do you like the evaluation system in PE.* 72.2% of Estonian boys and 91.5% of Finnish boys answered *yes* (χ^2 (1, n=150)=9.267, p<0.05). For girls, 59.0% of Estonian and 83.6% of Finnish girls answered *yes* (χ^2 (1, n=116)=8.461, p<0.05). Estonian and Finnish boys and girls reported that evaluation is based on too much on performing on general standards although evaluation should measure more individual development and how does the individual push during the PE classes.

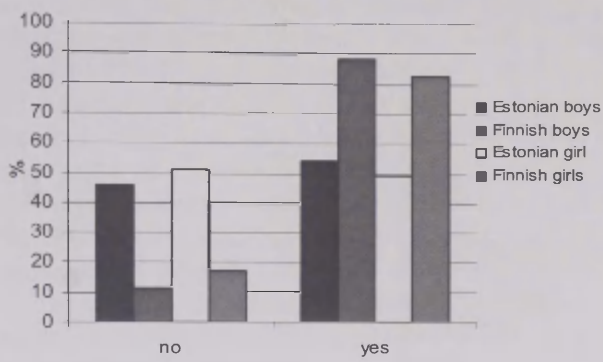

Figure 1. Students' opinion when asked if there was anything that bothers in the PE lessons.

The results of study revealed that 43.6% of Estonian boys and 60.6% of Finnish boys reported that there should be more PE lessons in schools (χ^2 (1, n=149)=4.288, $p<0.05$). From girls, 22.9% of Estonians and 44.6% of Finnish reported that there should be more PE lessons in schools (χ^2 (1, n=117)=2.877, $p>0.05$).

When asked about the conditions to carry out the PE lessons, 7.9% of Estonians and 16.4% Finnish reported that the conditions are very good. 40.7% of Estonians and 60.2% of Finnish rated PE conditions as good. 39.3% of Estonians and 18.8% of Finnish rated PE conditions as moderate and 12.1% of Estonian and 4.7% of Finnish as poor. Chi-square test revealed that the percentage of these answers were statistically different between Estonian and Finnish students: χ^2 (3, n=268)=23.044, $p<0.05$. Results showed also the differences between the Estonian and Finnish boys and girls (Figure 2).

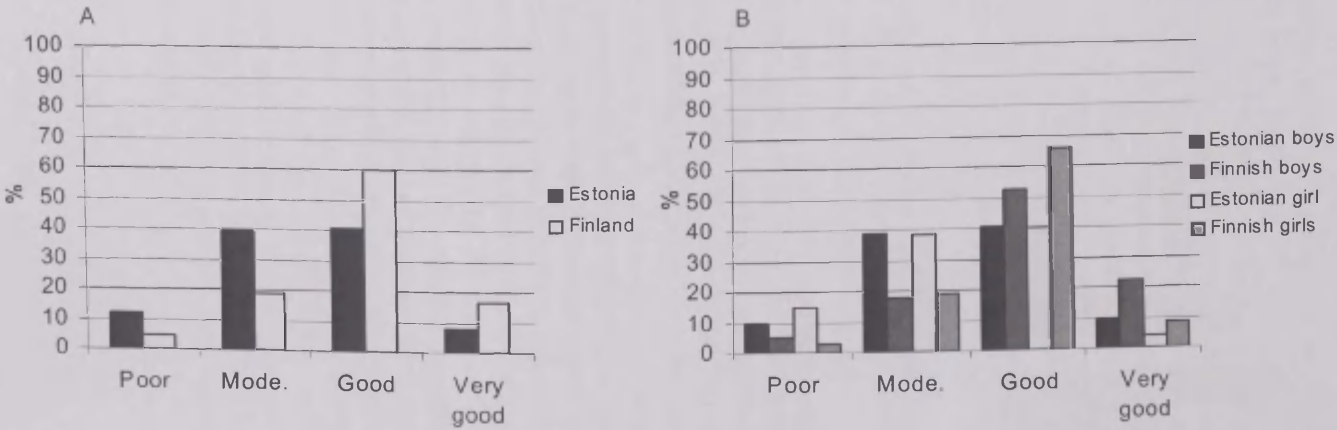

Figure 2. Students' opinion when asked about the conditions to carry out PE (A) as taken answers from boys and girls together and (B) separately.

The results were following when asked about the sanitary conditions after physical education classes. The sanitary conditions rated as *very good* 14.4% of Estonians and 14.8% of Finnish, as *good* rated 18.0% of Estonians and 50.0% of Finnish, as *moderate* rated 29.5% of Estonians and 31.3% of Finnish and as *poor* rated 38.1% of Estonians and 3.9% of Finnish (Figure 3). The answers were statistically different between Estonian and Finnish students: χ^2 (3, n=267)= 56.495, $p<0.05$. Estonian student's reported that there were no enough showers for students or rooms were narrow, the condition of the locker room or the shower room was bad, locker rooms and shower rooms were dirty or smelly and there were frequently no warm water coming from the showers.

Figure 3. Students' opinion when asked about the sanitary conditions after PE lessons.

Motivation in physical education

An independent-samples t-test was conducted to compare Estonians and Finnish graduating seniors amotivation, intrinsic motivation and external motivation. There was no significant differences in amotivation between Estonian (M=2.5±1.1) and Finnish boys (mean=2.3, SD=1.3) [t(137)=0.96, p=0.34]; in intrinsic motivation between Estonian (mean=4.3, SD=1.3) and Finnish (mean=4.7, SD=1.3) boys [t(137)=–1.89, p=0.06]; nor in external motivation between the Estonian (mean=3.8, SD=1.3) and Finnish (mean=4.2, SD=1.3) boys: [$t(137)=-1.58$, $p=0.12$].

The motivational responses towards physical education among Estonian and Finnish girls revealed that there were no significant differences in amotivation between Estonian (mean=2.6, SD=1.3) and Finnish (mean=2.5, SD=1.1) girls [$t(115)=0.3$, $p=0.76$]; nor in intrinsic motivation between Estonian (mean=4.4, SD=1.3) and Finnish (mean=4.2, SD=1.1) girls [$t(111)=1.04$, $p=0.3$]. There was, however, a significant difference in external motivation between the Estonian (mean=4.0, SD=1.1) and Finnish (mean=3.5, SD=1.0) girls [$t(115)=2.39$, $p=0.02$]. The external motivation of Estonian girls was significantly higher compared to Finnish girls.

DISCUSSION

Finnish and Estonian graduating seniors' opinions about their health and leisure time physical activity

The Estonian and the Finnish girls rated their health as *moderate* and as *good.* However, Estonian and Finnish boys rated their health as *very good.* Fair or poor self-rated health tends to be more common among older children and girls [16]. Although most of the Finnish girls did not rate their health as *very good,* they reported the highest percentage when the frequencies of leisure time physical activity were over four times a week. The minimum recommendations of daily PA for 18-year-olds are at least one hour [6], so results revealed that only a small group of Estonian and Finnish graduating seniors are reaching the limit of being physically active at least one hour per day. As Bugge et al. [2] reported, many children do not meet current recommendations of physical activity and that may become a threat to the health of the up-coming adult population. Findings revealed that the most popular way of making sports among Estonian graduating seniors were training in sport clubs where as in Finnish graduating seniors the most popular way of making sports was with friends and without coaching. However, the study revealed that there were no significant differences between the Estonian and Finnish pupils in health and leisure time physical activity.

Finnish and Estonian graduating seniors' opinions about physical education

Findings revealed that more than half of the Estonian and Finnish boys and girls reported that PE lessons are important. Bibik et al., [1] studied High school students' attitudes toward their physical education programs in the state of Delaware and descriptive analyses revealed that 43.5% of both high school boys and girls rated physical activity to be important in their high school studies. Compared findings above-mentioned Estonian and Finnish graduating seniors' opinions were more positive about importance of PE. Estonian and Finnish students' opinions about enjoyment and interest in PE were also very high. Bibik et al., [1] reported that, the students' enjoyment of physical education is significantly correlated with attribution of team sports (such as basketball, baseball, floor hockey and volleyball), fitness activities (aerobic dance, weight training, bicycling), individual games (tennis, badminton, track, pickle ball), and self-defense (wrestling, karate, judo) in the physical education curriculum. The positive attitude and perception of students towards physical activities are the main elements in evaluating the success of a particular Physical Education curriculum [13]. It is possible that because of the high level of enjoyment and interest toward PE that both Estonian and Finnish students reported in this study, their consider PE also as important.

When it was asked about the students' relationship with their PE teacher and classmates, findings revealed that Estonian boys opinions were a bit positive compared to Finnish boys. As for girls, Estonian girls reported a very good relationship with the PE teacher compared to Finnish girls. Opinions about the relationships to classmates were more equal between the Estonian and Finnish girls but Estonian girls opinions were however little bit more positive. Bibik et al. [1] wrote that the students in the latter study appeared to engage in more active behavior in physical education classes when they received interest and positive reinforcement from their peers. Finding in the present study is not similar, when referring to the Bibik et al. [1] study, although Estonian girls' relationships toward PE teacher and classmates are more positive, there are no significantly different in the opinions about PE classes between the Estonian and the Finnish girls.

Compared to the Estonian boys and girls most of the Finnish boys and girls reported that there is something that bothers in PE classes. Many of Estonian and Finnish students reported that PE classes are boring because they are doing all the time the same sports or exercise workouts. Considering that one of the important goals is to foster students' interest in physical education, it is crucial for physical educators to present learning activities in interesting, novel, and meaningful ways, and create a safe and caring learning environment to enhance students' situational interest in physical education [7]. Findings are similar to the findings of Bibik et al., [1], who revealed that approximately 21% of students responded that physical educators should teach more sports or games while approximately 13% indicated physical educators should teach more skills and strategies and 7.3% responded that students should learn more about fitness. Only 2.5% of the students responded that there was nothing they liked about physical education. Findings revealed that compared to Estonian graduating seniors, many of the Finnish graduating senior reported that they don't like the evaluation system in PE. Finnish boys and girls but also Estonian boys and girls reported that evaluation is based too much on performing of general standards although evaluation should measure more individual development and how individual pushes during the PE classes.

Compared to Estonian students, Finnish students' opinions were more positive when asked about should there be more PE lessons in schools. Estonian girls had the most negative opinions about extra PE classes. However, findings revealed that most of the Estonian girls were ready to have more optional PE lessons for choosing in schools. Also Estonian boys had positive opinions for having more optional PE lessons. Reason why Estonian boys and girls have so positive feelings about having more optional PE lessons for choosing in school is probably, because High Schools in Finland it is already possible to choose more PE classes.

One of the strongest findings indicated that there was a significant difference between the Estonian and Finnish graduating seniors when asking about the conditions to carry out the PE lessons and the sanitary conditions after PE lessons. Estonian student reported conditions to carry out PE lessons as *moderate* and as *good.* Most of the Finnish student reported conditions as *good.* Most of the Estonian students reported sanitary conditions as *poor* or as *moderate.* Finnish students reported the sanitary conditions as *good.* Comfort in the locker room may have a significant impact on their enjoyment of physical education with those feeling the most uncomfortable also enjoying physical education less [1]. Research in this area identifies curriculum content, classroom environment, and teacher behavior as the primary determinants of negative and positive attitudes toward physical education [4].

Finnish and Estonian graduating seniors' motivation in physical education

The study revealed that there were no significant differences in amotivation, intrinsic or extrinsic motivation between Estonian and Finnish boys. The motivational responses towards physical education among Estonian and Finnish girls revealed that there were no significant differences in amotivation or in intrinsic motivation between Estonian and Finnish girls. The study revealed however a significant difference in external motivation between the Estonian and Finnish girls. The external motivation of Estonian girls was significantly higher compared to Finnish girls. There are several reasons to external motivation. In this study it revealed that the one of the main reasons for higher external motivation might be because of poor to moderate conditions of sanitary and classrooms. As mentioned before findings revealed that Estonian girls had very good relationships to PE teachers and classmates. Therefore the reasons for the Estonian girls high extrinsic motivation might be that they avoid confrontation from the PE teachers or they feel that they should participates in PE because of that is what "good students" do. PE must provide an enjoyable experience such that students do not feel that they are taking part in PE because of external rules or feeling of guilt [15].

The results in the cross-cultural study by Caune and Hein [3] revealed that the comparison of the types of motivation showed that Estonian children evaluated all motivation types higher than Latvian children. As mentioned, results in the present study revealed that there are no significant differences about the types of motivation between Estonians and Finnish students compared to Estonian and Latvian students.

Large epidemiological studies in the United States, the Netherlands, and Finland indicate that the largest decrease in physical activity levels occurs during early adolescence. This trend parallels age-related declines in intrinsic motivation and other adaptive indices of motivation in compulsory school PE classes. Such decreases are problematic, given that positive experiences in school PE are related to physical activity participation during leisure time [12].

REFERENCES

1. Bibik J. M., Goodwin S. C., Omega-Smith E. M. (2007) High school students' attitudes toward physical education in Delaware. Phys. Educat. 64: 192–204
2. Bugge A., Hermansen B., Froberg K., Andersen L.B. (2009) The CoSCIS. (Copenhagen School Child Intervention Study). 25th International Symposium of Pediatric Work Physiology: Physical activity and Exercise for disabled and Healthy children. Paris, September 29th – October 3rd, 2009.
3. Caune A., Hein V. (2011) Differences of the constructs related to motivation in physical education among Latvian and Estonian schoolchildren. In: Acta Kinesiologiae Universitatis Tartuensis. Fourth Baltic Conference in Exercise and Sport Sciences. April 7–9.2011, Jürimäe T., Pääsuke M., Jürimäe J. (eds). 16(suppl): 32.
4. Constantinou P., Manson M., Silverman S. (2009) Female Students' perceptions about gender-role stereotypes and their influence on attitude toward physical education. Phys.l Educat. 66: 85–96
5. Daigle K., Hebert E. P. (2005) Development of an instrument to assess student attitudes toward physical education and physical activity intentions. RQES 76: A51
6. Finnish Ministry of Education. (2008) Koulu_PDF/080129Liikuntasuosituskirja (kevyt)
7. Gao Z., Newton M. (2009) Examining the mediating role of strategy use on students' motivation and persistence/effort in physical education. J.Sport Behav. 278–297
8. Hein V., Pihu M., Koka A. (2004) Intention to be physically active after school graduation and its relationship to three types of intrinsic motivation. Eur. Phys. Educ. Rev. 10: 5–19
9. Jaakkola T. (2002) Changes in students' exercise motivation, goal orientation, and sport competence as a result of modifications in school physical education teaching practices. Research Reports on Sport and Health 131. Doctoral thesis. Jyväskylä: LIKES-Research Center
10. Koka A., Hein V. (2005) The effect of perceived teacher feedback on intrinsic motivation in physical education. Int. J.Sport Psychol. 36: 91–106
11. Lumpkins A. (2008) Introduction to physical education, exercise science, and sport studies. 7 ed. Mc Graw Hill. 28–342
12. Ntoumanis N., Standage M. (2009) Motivation in physical education classes: A self-determination theory perspective. Theor. Res. Educ. 7: 194

13. Omar-Fauzee M.F., Jamalis M., Yusof A., Zarina M., Dev R., Dev O., Peddle M.Y., Norazemi A.G., Junaidi A.R., Dewi A.M., Latif R.A., Johar M., Nasaruddin M.N. (2009). College students perception on physical education classes during their high school days. Eur. J. Soc. Sci. 7: 4
14. Pelletier L.G., Fortier M.S., Vallerand R.J., Tuson K.M., Brie`re N.M., Blais M.R. (1995) Toward a new measure of intrinsic motivation, extrinsic motivation, and amotivation in sports: The SMS (Sport Motivation Scale). J. Sport Exerc. Psychol. 17: 35–53
15. Wang C.K.J., Liu W.C. (2007) Promoting enjoyment in girls' physical education: The impact of goals, beliefs, and self-determination. Eur. Phys. Educ. Rev. 13: 145–164
16. WHO, HBSC 2005/2006. (2007) (Health Behavior in School-aged Children). International report from 2005/2006 survey
17. Yli-Piipari S., Watt A., Jaakkola T., Liukkonen J., Nurmi J.E. (2009) Relationships between physical education students' motivational profiles, enjoyment, state anxiety, and self-reported physical activity. J. Sports Sci. Med. 8: 327–336

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BIODYNAMIC CHARACTERISTICS OF VERTICAL AND DROP JUMPS

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ABSTRACT

The aim of the study was to establish the main kinematic and dynamic parameters that generate the efficiency of vertical and drop jumps. The take-off power was assessed using the following tests: counter-movement jump, counter-movement jump with arm swing, jump, drop jump and continuous jump. Kinematic and dynamic parameters of vertical and drop jumps were established using two separate force-plates Kistler Type 9286A and a synchronised 3-D kinematic system CCD SMART-600E. The athlete model was defined with 17 markers sensitive to infra-red light. It was established that the main generators of efficiency in vertical and drop jumps included: take-off velocity, eccentric-concentric time, eccentric impulse, ground contact time and ankle flexion.

Key words: diagnostics, kinematics, dynamics, vertical jump, drop jump.

INTRODUCTION

The movement structures that occur in specific sport situations are associated with different inputs of eccentric and concentric muscle contractions. The aim of training is often to modify the eccentric muscle contraction in view of its neurological characteristics. A good understanding of the role of eccentric muscle contraction in sport activities facilitates adaptation through the application of apposite training resources. The eccentric-concentric cycle consists of muscle stretching due to an external force and muscle shortening in the second phase, i.e. a stretch-shortening cycle (SSC) [12]. In the eccentric phase, a limited quantity of elastic energy accumulates in the muscle-tendon complex to be used in the second phase. This portion of elastic energy that is accumulated in the muscle is only available for a specific time. The available time depends on the life span of the cross-bridges and lasts from 15 to 120 milliseconds [8, 10, 14]. As regards the production of force, it is essential that the muscle develops more force and consumes less chemical energy during an eccentric contraction compared to a concentric contraction [2, 10, 12, 13]. The efficiency of an eccentric-concentric contraction also depends on the time of the transition. The longer the time, the less efficient is the contraction. In addition to the extent and velocity of the change in the muscle's length and the duration of the transition, the efficiency of an eccentric-concentric contraction largely depends on pre-activation [9]. The latter defines the first contact of the foot with the ground. Pre-activation prepares the muscles for stretching and is manifested in the number of attached cross-bridges and the change in the excitability of ά-motor nerves. Both factors affect the short-range stiffness of the muscle. Greater muscle stiffness causes a marked extension of the ligaments and the tendon which, in turn, reduces the consumption of chemical energy in the muscle. The reduced consumption of chemical energy is particularly important in those motor situations where specific movements must be made at a high velocity (e.g. the action of the ankle joint in a sprint, the take-off action in long jump, high jump and triple jump).

Even though the eccentric-concentric type of force production is very common in different human movements, it only became the focus of research relatively late. The first studies of this subject were conducted by Flitny and Hirst (1978) using an isolated muscle of a frog. The positive transfer of preliminary muscle stretching on the contractile characteristics of muscles in motor situations was first established by Asmussen and Bonde-Petersen [1] and Cavagna [8].

In functional and anatomical terms, the main role in a vertical jump is played by the two-joint thigh muscles which are also referred to as hamstrings or ischio-crural muscles by some authors [7, 19]. This muscle group includes: m. semimembranosus, m. semitendinosus and

m. biceps femoris. In specific sport situations these muscles are responsible for the primary extension of the hip joint in a closed kinetic chain and for flexion of the knee joint. The length of the two-joint thigh muscle is highly variable, depending largely on the position of the knee and hip joints [18]. Its efficiency is best manifested in conditions of the high angular velocity of the joints of lower extremities. For that reason, the thigh muscles play an important role in fast explosive moves of acyclic and cyclic types.

Due to the inter-segmentary transmission of energy and the optimisation of the take-off action, the thigh muscles' activity is important in vertical jumps in conditions of a concentric or eccentric-concentric muscle contraction [18, 20]. With vertical jumps, the muscles engage in the take-off action following the proximal-distal principle of muscle activation. In the first phase of the jump when the vertical velocity of the body's centre of gravity increases, the extensors of the trunk and hip are the most active muscles. The key role in this phase of the take-off action is played by m. gluteus maximus which is able to develop great force due to the relatively low angular velocity of the hips. The thigh muscles generate the peak activation at the beginning of the hip extension [7]. In the continuation of the take-off action, the knee extensors engage and the energy is transmitted from the hip to the knee through m. rectus femoris. The last phase of the take-off is performed by the two-joint shank muscle (m. gastrocnemius). The explosive performance of vertical jumps primarily depends on the optimal co-ordination of one- and two-joint muscles. Zajac [20] established that one-joint muscles generate the initial propulsive energy for vertical jumps, whereas two-joint muscles control the intermuscular co-ordination and the final vertical impulse. The method used for establishing the activation of muscles based on their electrical activity is electromyography (EMG).

In many sports, vertical and drop jumps are an important exercise resource in an athlete's power training. They enhance the eccentric-concentric muscle contraction of the lower extremities. At the same time, they are an indispensable measurement instrument in take-off power diagnostics. As regards their movement structure, vertical and drop jumps are similar to real motor situations in sports practice. Different test batteries are used to diagnose the explosive power of the lower extremities, either of a laboratory or a situational/field type. Bosco [5] developed a classical protocol to monitor take-off power based on vertical jumps. Take-off power in conditions where the active muscles first extend (eccentric contraction) and then shorten (concentric contraction) is measured by means of a countermovement vertical jump and a drop jump. Continuous jumps can be used as an instrument to measure reactive explosive power. This study aimed to, establish the main dynamic and kinematic parameters that generate the efficiency of vertical and drop jumps.

METHODS

Experimental procedure

In the experimental procedures, two elite athletes – triple jumpers – took part (M. Š.: age 29 years, height 173.5 cm, body mass 59.0 kg; and M. G.: age 21 years, height 181.4 cm, body mass 60.0 kg) as well as two elite sprinters (M. O.: age 28 years, height 179.8 cm, body mass 75.6 kg; and J. G.: age 26 years, height 181.4 cm, body mass 79.6 kg). The athletes performed jumps in the following order: squat jump, countermovement jump, drop jump and continuous jumps. Each jump was performed three times. A system consisting of nine CCD SMART-e 600 video cameras (BTS Bioengineering, Padua) with a 50 Hz frequency and 768 x 576 pixel resolution was used for a 3-D kinematic analysis of vertical jumps (Figure 1). Kinematic parameters were processed by the BTS SMART Suite programme. A dynamic model featuring a system of 17 markers sensitive to infra-red light was defined (head, shoulders, forearm, upper arm, trunk, hips, thigh, shank, foot). The validity of the model was checked against the sequence of walking in the sagittal and frontal planes. The dynamic parameters of vertical and drop jumps were established by using two independent force plates (Kistler, Type 9286A). The sampling frequency was 1,000 Hz. The analysis was based on the following dynamic parameters: peak ground reaction force, force impulse and amount of work per 1 kg of body mass (concentric work J/kg). The ground reaction force was measured uni- and bilaterally. The statistical analysis of the results was processed with the SPSS statistical software.

Figure 1. Drop jump 25 cm – kinematic and dynamic parameters

RESULTS

According to the standard test protocol [5] a vertical and drop jumps is initiated from a stationary upright posture, with the knee angle measuring about 90 ^{0}. The jumps were performed with arms kept akimbo. The tests measured the eccentric – concentric component of speed strength. The measurement procedure was based on two separate Kistler force plates. The jumps height depends on the extensor muscles of the ankle, knee and hip joints. Based on the ground reaction force measured by force plates, and the 3D kinematic analysis the following kinematic and dynamic parameters were investigated (jump height, ground contact time, eccentric time, concentric time, flight time, jump efficiency, take-off velocity, peak force, eccentric-concentric impulse, hip fleksion, knee fleksion and ankle fleksion) (Table 1, 2, 3, 4).

Table 1. Dynamic and kinematic parameters of a countermovement vertical jump

COUNTERMOVEMENT JUMP	UNIT	A	B
Jump height	cm	48.8±0.3	40.8±0.1
Ground contact time	ms	364±10	338±9
Eccentric time	ms	123±9	131±8
Concentric time	ms	241±6	207±15
Concentric work	J/kg	6.4±0.3	5.1±0.1
Jump efficiency	cm/J	7.6±0.4	7.9±0.1
Peak power	W/kg	50.1±0.9	45.8±0.1
Flight time	ms	590±1	525±1.9
Take-off velocity	m/s	2.47±0.3	2.42±0.3
Peak force	N	904±1.5	1104±25
Eccentric impulse	Ns	34±1	96±3
Concentric impulse	Ns	178±2	145±1
Hip flexion	deg	77±1	69±2
Knee flexion	deg	89±3	88±2
Ankle flexion	deg	32±1	38±2

Table 2. Dynamic and kinematic parameters of a countermovement vertical jump with an arm swing

COUNTERMOVEMENT JUMP – WITH ARM SWING	UNIT	A	B
Jump height	cm	55.0±1.7	47.3±0.5
Ground contact time	ms	372±11	408±17
Eccentric time	ms	158±8	128±8
Concentric time	ms	214±11	280±7
Concentric work	J/kg	6.4±0.3	5.8±0.1
Jump efficiency	cm/J	8.6±0.2	8.1±0.1
Peak power	W/kg	57.3±2.2	49.3±0.6
Flight time	ms	633±9	578±5
Take-off velocity	m/s	2.80±0.4	2.68±0.3
Peak force	N	1029±23	827±6
Eccentric impulse	Ns	93±3	39±4
Concentric impulse	Ns	181±5	174±1
Hip flexion	deg	74±3	70±2
Knee flexion	deg	88±2	96±1
Ankle flexion	deg	31±1	40±1

Table 3. Dynamic and kinematic parameters of a drop jump from a height of 25 cm

DROP JUMP – 25 cm	UNIT	A	B
Jump height	cm	47.3±0.8	38.6±0.8
Ground contact time	ms	165±5	174±3
Eccentric time	ms	73±2	80±2
Concentric time	ms	92±2	94±1
Concentric work	J/kg	5.1±0.2	4.3±0.1
Jump efficiency	cm/J	9.3±0.3	9.0±0.3
Peak power	W/kg	92.4±6.7	76.6±1.2
Flight time	ms	580±3	503±6
Take-off velocity	m/s	2.78±0.1	2.65±0.4
Peak force	N	3654±108	3689±180
Eccentric impulse	Ns	161±4	151±3
Concentric impulse	Ns	164±1	141±2
Hip flexion	deg	26±1	29±1
Knee flexion	deg	56±2	61±2
Ankle flexion	deg	13±1	25±1

Table 4. Dynamic and kinematic parameters of continuous jumps (n=20)

CONTINUOUS JUMPS (N =20)	UNIT	C	D
Jump height	cm	33.3±1.5	37.5±3.8
Ground contact time	ms	156±4	252±19
Eccentric time	ms	79±6	128±8
Concentric time	ms	76±3	124±11
Concentric work	J/kg	3.1±0.2	4.0±0.4
Jump efficiency	cm/J	10.8±0.5	9.4±0.2
Peak power	W/kg	66.3±4.4	58.8±7.1
Flight time	ms	445±13	452±34
Index activity		0.35±0.2	0.55±0.4
Take-off velocity	m/s	2.19±0.7	2.59±0.2
Peak force	N	4224±393	2735±363
Eccentric impulse	Ns	165±17	171±23
Concentric impulse	Ns	155±16	201±26
Hip flexion	deg	12±3	22±6
Knee flexion	deg	27±3	46±4
Ankle flexion	deg	6±2	18±2

DISCUSSION

This motor task consists of a rapid lowering of the body's centre of gravity, whereby the active leg muscles stretch (eccentric contraction). Then the movement is halted and the subject immediately takes off in a vertical direction (concentric contraction). The energy that accumulates in the muscles and the tendon during the stretching is transmitted to the concentric phase. Consequently, the velocity of movement in the second phase increases. The jump is performed with arms kept akimbo. The measurement protocol was based on the following parameters (Table 1). The take-off time ranges from 338 to 364 milliseconds. According to the principle of elastic energy transfer, the eccentric phase is shorter than the concentric one. Subject A, whose jump height was 48.8 cm, had an eccentric/concentric phase ratio of 33.8% : 66.2%. For subject B, whose jump height was 40.8 cm, the respective ratio was 38.7% : 61.3%. It can be concluded that the efficiency of the two-phase muscular activity depends on an appropriate ratio between the eccentric and concentric muscle contraction. The elastic energy generated in the first phase thus accumulates in the muscle-tendon complex (tendon, aponeurosis, cross-bridges, perimysium, epimysium and sarcolemmas; [3, 4]) and merges with the chemical energy of the muscle in the concentric phase. The consequence is a larger muscle force, resulting in a higher jump. The vertical velocity of the body's centre of gravity in a two-phase muscle contraction is 9.5% higher than in a single-phase concentric muscle contraction. The transition from eccentric to concentric contraction takes place when the knee angle measures 89°. The ground reaction force ranges between 904 N and 1104 N.

A countermovement vertical jump can be performed with or without an arm swing. According to the classical protocol [5], the arms were isolated and kept akimbo. In some motor situations it is important to know what the contribution of the arms is to the efficiency of a vertical jump (e.g. in volleyball). The arms contribute 8.6% to 8.8% to the jump height (Table 2). The arm swing changes some kinematic and dynamic parameters of a vertical jump. For study subject A, the ground contact time was longer, especially the eccentric phase, while increases were recorded in the ground reaction force – by 125 N, take-off velocity – by 0.33 m/s and the force impulse in the eccentric contraction – by 59 Ns.

Drop jumps are an extremely efficient means to improve how the ankle muscles function in eccentric-concentric conditions. At the same time, they are used in take-off power diagnostics. The degree of loading in drop jumps is defined by the jump depth, the athlete's body mass, contact time and vertical jump height. The jumps are performed from a height of 25 cm to 80 cm. Jumps from a height of 80 cm or more constitute a risk of injury which is why they are usually warned against in training practice. These jumps put the bulk of loading on the plantarflexors and the knee and hip extensors. The landing must be performed in such a way as to prevent the heel from touching the ground. The bumping of the heel against the ground causes a rise in the ground reaction force of more than 100%. If braking in the eccentric phase cannot be performed by the ankle joint extensors, the task is taken over by the knee and hip extensors. However, in this case, the time of the transition from the eccentric to the concentric phase is substantially longer, thus negatively affecting the efficiency of the jump.

A drop jump consists of the following phases: leaving the bench set at a specific height, flight, preparation for landing, ground contact, braking, eccentric-concentric contraction and vertical acceleration. Not only is the height of the bench important, but so too is the peak height of the body's centre of gravity during the flight phase. The pre-activation phase starts 100 milliseconds before the ground contact [9, 11]. The function of the muscle pre-activation is to prepare the muscle for stretching. This pre-activation is secured by the concurrent activation of m. gastrocnemius and m. tibialis anterior. The short-range stiffness of m. gastrocnemius thus facilitates the accumulation of a higher quantity of elastic energy in the tendon and a smaller extension of the muscle [9]. The purpose of drop jumps is to shorten the time of shock absorption which generates an optimum transition from the eccentric to the concentric contraction. The analysis of drop jumps was based on the following parameters (Table 3).

Contact time is one of the crucial parameters of drop jumps as it defines the efficiency of the transition from the eccentric to the concentric contraction. The contact time of the study subjects who performed a drop jump from a height of 25 cm ranged from 165 to 174 milliseconds. The ratio between the time of the eccentric and concentric phases of subject A was 44.2% : 55.8%, whereas that for subject B was 45.9% : 54.1%. Subject A expressed greater efficiency in braking after landing from a 47.3 centimetre-high jump. Some authors [11, 19] have shown that the pre-activation of plantarflexors is the most important mechanism in shortening the contact time in eccentric-concentric motor tasks. Basically, the central motor programme improves and – through control of musculature activation – increases the short-range stiffness of the muscle-tendon complex of the lower extremities upon contact with the ground. This programme is responsible for synchronisation of the ankle joint flexors and extensors. The optimum pre-activation of agonists and antagonists prior to contacting the ground reduces the amplitudes of movement and shortens the eccentric phase. Consequently, a larger muscle force is generated, along with a lower consumption of metabolic muscle energy. The shortening of the ground contact time in a drop jump is mainly the result of the pre-activation of m. gastrocnemius, m. soleus and m. tibialis anterior [11]. The efficiency of the performance of drop jumps in subject A (this athlete is an elite triple jumper) compared to that in subject B is primarily reflected in the following parameters: a shorter contact time, a shorter eccentric phase, peak power (W/kg of body mass), a higher take-off velocity, a higher force impulse in the eccentric and particularly the concentric phase as well as a lower amplitude of movement in the knee and ankle joints. Short-range muscle stiffness is additionally manifested in the ankle joint since the amplitude of the movement of subject A was only 13°, whereas that of subject B was 25°. The peak ground reaction force, measured by two force plates (Kistler, Type 9286A), was 3654 ± 108 N in the case of subject A and 3689 ± 180 N in the case of subject B (drop jump from 25 cm). The peak ground reaction force and the peak force impulse were recorded in the eccentric phase.

The test consists of a series of continuous vertical jumps (Table 4), with the emphasis put on the take-off from the ankle joint. The arms are kept akimbo, while attention must be paid to a correct body balance. The subjects of the present study performed 20 vertical jumps. The test assessed the degree of the elastic (reactive) power of the plantarflexors which play the key role in real motor situations such as sprint, hurdles, long jump and triple jump. The test result is defined by the average height of the jumps, the average time of flight and the ground contact phases, the average duration of eccentric and concentric phases, the peak ground reaction force and the realised average power per 1 kg of the subject's body mass (W/kg).

Study subject C, who is an elite world class sprinter, recorded very short contact times, averaging 156 ± 4 milliseconds. The eccentric phase lasted only 79 milliseconds. The velocity of the eccentric-concentric cycle reveals the efficiency of the transformation of kinetic energy to elastic energy, with major roles being played by the elastic and reflex components of the muscle-tendon complex. The shorter the phase during which the muscle-tendon complex stretches and the smaller the amplitude of movement in the ankle (6°), the better the utilisation of elastic energy [6, 15]. In terms of the movement structure and generation of force within a short time interval, the test is very similar to that for sprinting. Sprinting is a typical example of an eccentric-concentric cycle. In the eccentric contact phase, the muscle-tendon complex extends, whereby the accumulated elastic energy is consumed in the efficient propulsion of the running stride. In the phase of peak sprint velocity, the contact phase time ranges between 85 and 90 milliseconds, with the vertical component of the ground reaction force equalling 1400 to 2100 N [14]. Subject C develops a peak ground reaction force of 2265 ± 373 N and 1959 ± 413 N with their right and left legs, respectively. A certain degree of asymmetry between the lower extremities was identified. The obvious difference between study subjects C and D was seen in the short-range stiffness of their ankle and knee joints. Subject C's flexion of the ankle joint in vertical jumps was only 6 ± 2°, whereas that of subject D was 18 ± 2°.The greater short-range stiffness of the ankle joint in a sprint results in the lower consumption of chemical energy in the following muscles: m. gastrocnemius lateralis, m. gastrocnemius medialis and m. soleus. The lower consumption of chemical energy is important in those motor situations where a certain movement must be performed at a high velocity.

CONCLUSION

The biomechanical diagnostics of the explosive power of lower extremities is an extremely important element of monitoring modern athletes' training processes. The results of measuring different types of vertical and drop jumps provide us with fundamental information on the status and functioning of the neuromuscular system. Based on this information the training process can be far more accurately programmed and controlled in terms of power. Certain state-of-the-art technologies and measurement procedures for diagnosing explosive power have been presented, primarily as regards monitoring the dynamic and kinematic parameters of vertical and drop jumps. The tests are implemented in laboratory conditions, whereas the next step is to enable the monitoring of an athlete's neuromuscular system in field conditions, i.e. in a real environment.

REFERENCES

1. Asmussen E., Bonde-Petersen F. (1974) Storage of elastic energy in skeletal muscles in man. Acta Physiol. Scand. 91: 385–392
2. Bührle M., Schmidtbleicher D., Ressel H. (1983) Die spezielle diagnose der einzelnen kraftkomponenten in hochleistungssport. Leistungssport. 3: 11–16
3. Bobbert M., Huijing P., van Ingen Schenau G. (1987) Drop jumping I. The influence of jumping technique on the biomechanics of jumping. Med. Sci. Sport Exerc. 19: 332–338
4. Bobbert M., van Ingen Schenau G. (1988) Coordination in vertical jumping. J. Biomech. 21: 249–262
5. Bosco C. (1992) L'evaluation de la force par le test de Bosco. Roma, Societa Stampa Sportiva
6. Bosco C., Vittori C., Matteuci E. (1995) Considerazioni sulle variazioni dinamiche di alcuni parametri biomeccanici nela corsa. Atleticastudi. 2: 155–162
7. Brockett C., Morgan D., Proske U. (2004) Predicting hamstring strain injury in elite athletes. Med. Sci. Sports Exerc. 36: 379–387
8. Cavagna G. (1977) Storage and utilization of elastic energy in skeletal muscle. Exerc. Sport Sci. Rev. 5: 89–129
9. Dolenec A. (1999) Vpliv treniranja globinskih skokov s plantarno in dorsalno tehniko na delo gležnja pri globinskih skokih [Impact of training of drop jumps using plantar and dorsal technique on the work of ankle in drop jumps]. Doctoral dissertation, Faculty of Sport, Ljubljana
10. Enoka R. (2003) Neuromechanics of human movement. Human Kinetics, Champaign, IL
11. Gollhofer A., Kyrolainen H. (1991) Neuromuscular control of the human leg extensor muscles in jump exercises under various stretch-load conditions. Int. J. Sports Med. 12: 34–40
12. Komi P., Gollhofer A. (1997) Stretch reflex can have an important role in force enhancement during SSC exercises. J. Appl. Biomech. 13: 451–459
13. Mero A., Komi P. (1994) EMG, force, and power analysis of sprint-specific strength exercises. J. Appl. Biomech. 10: 1–13

14. Mero A., Komi P., Gregor R. (1992) Biomechanics of sprint running. Sport Med. 13: 376–392
15. Mero A., Kuitunen S., Harland M., Kyrolainen H., Komi P. (2006) Effects of muscle-tendon length on joint movement and power during sprint starts. J. Sport Sci. 24: 165–173
16. Markovic G., Dizdar D., Jukic I., Cardinale M. (2004) Reliability and factorial validity of squat and countermovement jump tests. J. Strength Con. Res. 16: 20–31
17. Newton R., Kraemer W. (1994) Developing explosive muscular power: implications for a mixed methods training strategy. J. Strength Cond. Res. 18: 551–555
18. Šarabon N., Fajon M., Zupanc O., Draksler J. (2005) Stegenske strune [Hamstrings injuries]. Šport. 3: 45–52
19. Schmidtbleicher D. (1992) Training for power sports. In: Strength and power sport, P. Komi (ed). Blackwell Scientific, London. 381–395
20. Zajac F. (1993) Muscle coordination of movement: a perspective. J. Biomech. 26: 109–124

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GAIT AND MUSCLE STRENGTH CHARACTERISTICS IN TOTAL KNEE ARTHROPLASTY PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME BEFORE AND SIX MONTHS AFTER SURGERY

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ABSTRACT

The aim of the present study was to investigate the gait and muscle strength characteristics in total knee arthroplasty (TKA) patients with patellofemoral pain syndrome (PFPS) before and six months after surgery. Eight patients (4 men and 4 women) aged 58–77 years with PFPS following unilateral TKA who had primary degenerative knee OA participated in the study before and six months after reoperation. In patients was registered the active range of motion (AROM) of knee extension and flexion, hip abduction and adduction. Isometric maximal voluntary contraction (IMVC) force of knee flexors, extensors, abductors and adductors was measured and gait kinematic characteristics and kinetic characteristics of knee joint were recorded. Knee flexion AROM in the involved leg was significantly lower ($p<0.05$) as compared to the uninvolved leg pre- and post-surgery. The patients had greater ($p<0.05$) hip abduction AROM and significant increase (31%, $p<0.05$) of IMVC force of the involved leg's hip abductors postoperatively as compared before surgery. Six months after surgery a significant ($p<0.05$) improvement of gait spatiotemporal characteristics (increase of swing time and stride length ($p<0.05$), together with decrease of stance time and cadence, as well increase of stride length) was noted in the involved leg. In TKA patients 6 months after reoperation due to PFPS the knee joint function in involved leg was significantly improved and the positive changes in gait with comfortable velocity took place as compared before surgery.

Key words: joint replacement, isometric contraction, osteoarthritis, anterior knee pain

INTRODUCTION

Patellofemoral complications following total knee arthroplasty (TKA) continue to be a significant source of postoperative morbidity and revision surgery. The possible complications include patellofemoral instability, extensor mechanism impairment, soft tissue impingement, prosthetic wear or loosening, and osteonecrosis [18]. Patellofemoral pain syndrome (PFPS) can be defined as anterior knee pain or retropatellar pain in the absence of other specific pathology [6].

Cooney et al [5] retrospectively reviewed 361 patients who had a revision total knee arthroplasty done for an extensor mechanism problem to assess the prevalence, etiology, and risk factors of subsequent reoperation. The prevalence of reoperation was 23% and 84 patients were reoperated for one or more times. The average time until the first reoperation was 2.4 years. The cumulative risk of a reoperation for any reason was 7% 1 year, 19.6% 5 years, and 35.9% 10 years after index revision. The authors found that the most common reason for reoperation was a new or recurrent patellofemoral problem, which accounted for 33% of the first reoperations. By data of Sierra et al [23] the average time from index revision total knee arthroplasty to the first reoperation was 3.5 years (range 1 day–19 years) and the cumulative risks of the first reoperation at 5, 10, and 15 years were 16.1%, 26%, and 31.4%, respectively.

A retrospective analysis of 2188 total knee arthroplasties performed during six years (2002–2007) in Tartu University Hospital revealed that reoperation was conducted in 2.1% of cases (47 patients). Reoperation burden was 1.5% in unconstrained GEMINI SL (LINK), 2.6% in semiconstrained PFC (De Puy) and 1.3% in constrained rotational hinged knee (LINK). Normal alignment of the PF joint in the axial X-ray was differentiated in 3 patients (6.4%) and other had lateral pressure syndrome – 34 patients (72.3%) and patellar subluxation or necrosis – 10 patients (21.3%) [11].

The level of ROM limitation and joint contracture localization define the functional limitations of a patient [4, 16]. It has been suggested that an imbalance between the vastus medialis and vastus lateralis muscle forces causes abnormal tracking of patella, resulting in reduced contact areas, increased stresses, and patellofemoral pain [3]. Knee extensor (KE) muscle forces play an important role in determining the medial-lateral force balance, contact force and pressure distribution of the patellofemoral joint [3, 8, 13]. In a review article [2] on kinematic gait characteristics associated with PFPS it was noted that during walking, individuals with PFPS can exhibit impaired ankle joint kinematics and a possible reduction in gait velocity. Previously, it has been demonstrated that persistent gait abnormalities are comparable between patients with different type of knee joint prostheses (posterior-stabilized, cruciate-retaining and cruciate-sacrificing prostheses) [26]. The data regarding the gait biomechanics for TKA patients with PFPS patients is not well documented.

The aim of our study was to investigate the gait and thigh muscle characteristics in TKA patients with PFPS before and six months after surgery. It was hypothesized that gait velocity and other kinematic data can be improved in TKA patients with PFPS 6 months after surgery.

MATERIALS AND METHODS

Subjects

Eight patients (4 men and 4 women, mean age 66 years, range 56–77; BMI 31.9 kg/m^2, range 26–39) with PFPS following unilateral TKA participated in the study before and six months after surgery (Table 1). Pre-TKA, all patients had primary degenerative knee OA in stage III or IV according to Kellgren-Lawrence Scale and were scheduled for the first TKA. The patients had patellofemoral compartment involvement in OA in the operated knee joint. The duration of symptoms before TKA was 9.3±2.5 years (range 3–20 years) and reoperation due to PFPS was performed 18.8±3.5 months (range 6–

36 months) later. Patients in the PFPS group were confirmed with the presence of pain and/or tenderness upon palpation of the patella; experienced diffuse anterior knee pain for at least 6–12 months and had increased knee pain when descending stairs and during physical activity. Exclusion criteria were any other joint replacement of lower limbs, other orthopaedic dysfunctions, rheumatoid arthritis, neuromuscular or neurodegenerative diseases, significant cardiac or pulmonal problems. The patients were evaluated twice: preoperatively and six months after reoperation. Before the beginning of the testing session, all subjects completed an informed consent form. The study carried the approval of the Ethics Committee of the University of Tartu.

Measures

Surgical procedures

For TKA, the condylar endoprostheses GEMINI (W. Link Gmbh & Co, Germany) with a rotating plateau were used in case of moderate knee varus deformity (up to 10°) and stable knee ligaments (in 4 patients). By using this type of prostheses the posterior cruciate ligament was retained. The condylar endoprostheses PFC with posterior joint stabilization (Johnson & Johnson, USA) were used in case of more severe knee varus deformity (up to 20–25°) and instable knee ligaments (in 4 patients). The posterior cruciate ligament was sacrificed in these cases. A fixed polyethylene insert was used. The patella was not resurfaced.

Two kinds of reoperations were performed in TKA patients with PFPS – patella endoprosthesis (resurfacing) or patella resection (reshaping).

Active range of motion

The knee flexion, extension, and hip abduction and adduction active range of motion (AROM) were measured by standard mechanical goniometer Gollehon Extendable Goniometer (Lafayette Instrument, USA) and standard guidelines [4]. Three measurements were taken for each joint and the best result was accepted for future analysis.

Isometric maximal voluntary contraction force

Thigh muscle isometric maximal voluntary contraction (IMVC) force in flexion, extension, abduction and adduction was measured by hand-held dynamometer (Lafayette Manual Muscle Test System, Lafayette Instrument Company, USA). Hand-held dynamometer is a reliable and valid assessment tool for measuring strength of the hip and knee muscle in older adults [1].

During the IMVC force testing of knee extensor muscle the subject was in seated position on a therapeutic table with knee flexed to aproximately 90°. IMVC testing of knee flexor muscle was performed in prone subject, flexion of the knee between 50° and 70° [12]. The subjects were required to exert maximum strength, pushing against the dynamometer for approximately 3 s as hard as possible with rest period of 1 min. The noninvolved leg was tested first, followed by the involved leg. The best result from three trials was taken as isometric maximal voluntary strength. All assessments were performed by the same physiotherapist.

Gait characteristics

Gait kinematic and kinetic characteristics were recorded using the ELITE motion analyzer with six infrared cameras with a sampling rate of 100 Hz and Elite Clinic software (BTS SpA, Italy). Twenty passive reflecting spherical markers with the diameter of 15 mm were attached to the selected anatomic points of body according to the Davis protocol [7]: three markers on the shoulders, three markers on the pelvis, three markers on each thigh, three markers on each calf and one marker on each foot. The subjects were requested to walk with at their comfortable velocity along a 5.3-m walkway. Three to five trials were recorded and the trial with stable walking cadence (without de- or accelerations) was taken for analysis.

The following spatiotemporal parameters of gait were recorded: walking speed, cadence, stride length, stance and swing time, single-limb and double-limb support time. Kinematic and kinetic characteristics of knee joint flexion and extension – range of motion and corresponding moment of force of knee joint flexion and extension were estimated. Gait characteristics were normalized to gait cycle (cycle duration = 100%).

Knee joint pain

Self-estimation of pain and stiffness of knee joint and physical function during recent 48 hours was performed using Western Ontario and McMaster Universities Index of Osteoarthritis (WOMAC) questionnaire [15]. The questionnaire includes 24 questions, five of which estimate pain, two – stiffness and 17 – functional ability. Smaller scores characterize greater impairment of function. Pain subscale (state without pain gives 20 points) and physical activity subscale (state with better physical activity gives 68 points) are included in Table 1.

Statistical analysis

Data are means and standard errors of means (± SE) and range (min-max). Student's paired t-test was used to find differences of data before and after reoperation and unpaired test to compare data of the involved and uninvolved leg. For WOMAC scores statistical analysis was performed using non-parametric tests (normality of scores distribution was tested within each group using the Kolmogorov-Smirnov test). Comparison of the post- to the preoperative scores was estimated by Wilcoxon test. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

In the present study TKA patients with PFPS reported to have less pain in knee joint and improved physical function ($p<0.01$) estimated by WOMAC scores (Table 1). The involved leg's knee flexion AROM was significantly lower as compared to the uninvolved leg pre- and post-surgery (Figure 1A). This characteristic of the involved leg did not change significantly ($p>0.05$) post-surgery as compared before it. The patients had greater hip abduction AROM of the involved leg 6 months after surgery as compared before it ($p<0.05$) (Figure 1B). AROM of knee extension and hip adduction of the involved leg 6 months post-surgery did not differ significantly ($p<0.05$) from pre-surgery data (data are not shown here).

Table 1. Anthropometric characteristics and WOMAC scores of TKA patients with PFPS before and 6 months after surgery (n=8)

Characteristics	Before surgery				6 months after surgery			
	Mean	**SE**	**min**	**max**	**mean**	**SE**	**min**	**max**
Age (year)	66.3	2.3	58	77	66.4	2.3	58	77
Height (cm)	169.4	4.6	148.5	189.2	169.7	3.4	148.5	189.2
Body mass (kg)	86.3	3.8	73.4	97.9	85.7	4.0	77.2	100.4
BMI (kg/m^2)	30.2	1.3	25.6	35.1	29.9	1.0	26.1	34.7
WOMAC-Pain (0–20)	5.4	1.2	5	12	12.0**	1.7	7	19
WOMAC-PF (0–68)	18.0	3.2	7	25	36.1**	3.4	16	45

TKA – total knee arthroplasty; PFPS – patellofemoral pain syndrome; BMI – body mass index, WOMAC – Western Ontario and McMaster Universities Index of Osteoarthritis questionnaire; WOMAC-Pain – pain subscale and WOMAC-PF – physical function subscale (smaller scores characterise greater impairment of function; estimation involved recent 48 hours before testing). Data are presented as mean ± SE and range (min-max). **$p<0.01$ as compared with data before surgery.

Six months after surgery lower IMVC force ($p<0.05$) of the involved leg in TKA patients with PFPS was noted as compared to the uninvolved leg (Figure 1C). The patients also demonstrated lower IMVC force ($p<0.05$) of the involved leg's hip abductor muscle pre-surgery as compared to the non-involved leg (Figure 1D). No significant differences were noted in this characteristic 6 months after surgery between the involved and uninvolved leg.

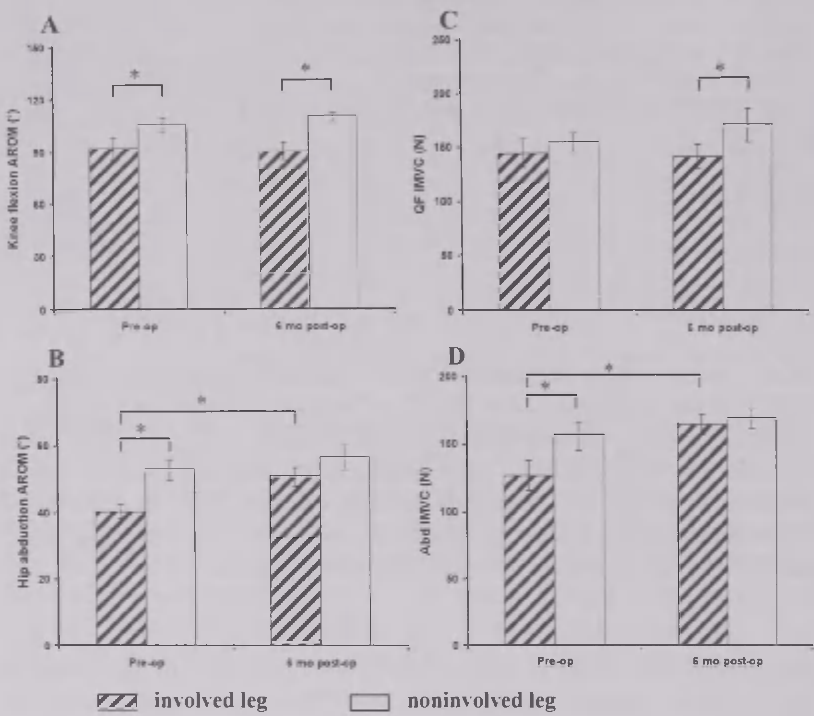

Figure 1. Active range of motion (AROM) and isometric maximal voluntary contraction (IMVC) force of knee joint flexion (**A** and **C**, respectively) and hip abduction (**B** and **D**, respectively) in total knee arthroplasty patients with patellofemoral pain syndrome before and six months after reoperation (mean and SE, $*p<0.05$).

Six months after surgery a significant increase of swing time ($p<0.01$) and swing time as per cent of stride ($p<0.05$) and stride length ($p<0.05$) of the involved leg were noted in patients as compared to pre-surgery (Table 2). Postoperatively patients demonstrated a decrease ($p<0.05$) of stance time and cadence as well increase ($p<0.05$) of stride length as compared to before surgery. Changes in spatiofemoral characteristics of gait are presented in Figure 2. The greatest differences of the above mentioned gait characteristics were noted in the swing time value (21%) (Figure 2).

Table 2. Spatiotemporal characteristics of gait of TKA patients with PFPS before and 6 months after surgery (mean and SE, n=8)

Characteristics	Leg	Before surgery 1		6 months after surgery 2		p (1–2)
		Mean	SE	Mean	SE	
Stance time (ms)	IL	714.1	38.7	761.3	41.0	NS
	NIL	727.4	44.1	746.9	34.6	NS
Swing time (ms)	IL	376.5*	28.9	474.4	26.8	0.008
	NIL	436.8	16.0	475.6	23.6	NS
Double support time (ms)	IL	133.5	15.9	135.0	11.2	NS
	NIL	125.4	12.4	141.3	16.2	NS
Stance time (% stride)	IL	66.6	1.3	61.1	0.9	0.023
	NIL	62.0	1.3	61.5	1.3	NS
Swing time (% stride)	IL	33.4*	1.3	38.9	0.9	0.023
	NIL	38.0	1.5	38.5	1.3	NS
Double support time (% stride)	IL	12.3	0.9	10.9	0.5	NS
	NIL	11.6	0.9	11.3	0.8	NS
Stride length (cm)	IL	106.5	4.7	118.1	4.6	0.050
	NIL	108.1	7.0	113.0	4.2	NS
Stride width (cm)		10.4	0.7	10.2	0.6	NS
Velocity (m/s)		0.96	0.07	0.97	0.07	NS
Cadence (step/min)		108.5	4.9	99.8	4.1	0.031

TKA – total knee arthroplasty; PFPS – patellofemoral pain syndrome; IL – involved leg; NIL – noninvolved leg; *$p<0.05$ as compared involved leg with noninvolved leg; NS – not significant difference ($p<0.05$) as compared data before and after surgery.

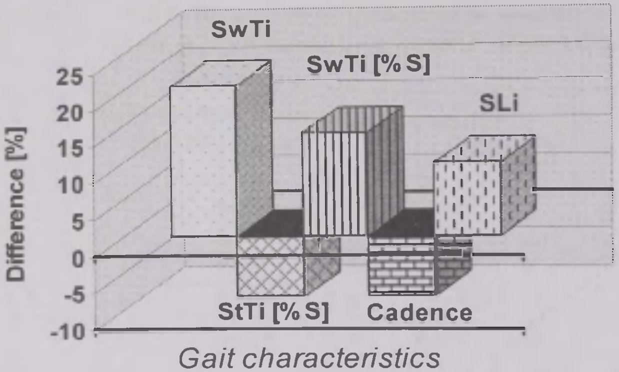

Figure 2. Changes in spatiotemporal characteristics of gait in total knee arthroplasty patients with patellofemoral pain syndrome six months after reoperation ($p<0.05$). Data before reoperation was taken as 100%. SwTi – swing time in ms ($p=0.008$), SwTi [%S], swing time as per cent of stride ($p=0.023$), SLi – stride length ($p=0.050$); StTi [%S] – stance time in ms of involved leg ($p=0.023$).

No significant differences ($p>0.05$) in other temporal and distance, as well as in kinematic and kinetic characteristics of knee joint as compared pre- and post-surgery were found. The tendency to improve the moment of force of knee joint flexion and extension was noted in patients 6 months after surgery (Figure 3).

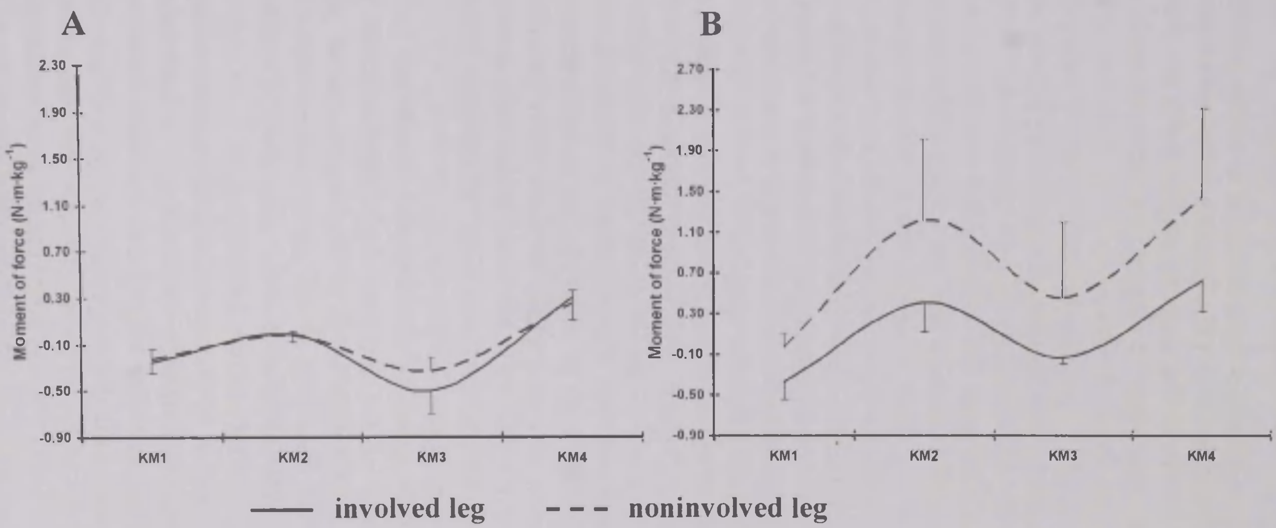

Figure 3. Moment of force of knee joint flexion and extension during gait cycle in knee arthroplasty patients with patellofemoral pain syndrome before (**A**) and six months after reoperation (**B**) (mean and SE; $p>0.05$). KM_1 – first maximum flexion moment after initial contact, KM_2 – first maximum extension moment in early stance, KM_3 – second max flexion moment in midstance, KM_4-second maximum extension moment in terminal stance.

DISCUSSION

The present study investigated gait spatiofemoral and knee joint kinematic and kinetic characteristics in TKA patients before and 6 months after reoperation due to PFPS. The main finding of the study was that 6 months after surgery take place: (1) significant improvement in self-estimated knee joint function; (2) increase of hip abduction AROM and IMVC force; and (3) improvement of few gait spatiofemoral characteristics (increase of stride length and decrease of gait cadence).

The high mean BMI was noted in patients with post-TKA PFPS. It has been reported that knee joint OA is associated with an increase in body mass and more obese subjects had the greater reduction of the KE strength [24]. In our study, patients demonstrated significant improvement of knee joint function by WOMAC scores after reoperation. In a retrospective study [22] where subjects were TKA patients aged 62–84 years (the post-surgery period was 6–7 years), no statistical significance was noted between men and women concerning differences in anterior knee pain after surgery.

TKA patients with PFPS demonstrated before and 6 months after surgery lower AROM (12% and 19%, respectively) and IMVC force (8% and 20%, respectively) of the involved leg for knee flexion as compared to the uninvolved leg. The incidence of flexion deformity following TKA is shown as high as 17% [25], but no differences were noted in knee extension of stance phase between TKA patients and healthy controls [10]. Previously it has been found that quadriceps muscle strength decrease in patients with orthopaedic problems evokes changes in body balance and gait [16].

In the present study, patients demonstrated significant increase (31%) of IMVC force of the involved leg's hip abductors post-operatively as compared before surgery. The importance of paying attention to appropriate balancing of the patellofemoral soft tissues was emphasized in studies of patellofemoral pain after TKA [20] and of the effect of soft tissues on patellar tracking [21].

Significant improvement of gait spatiofemoral characteristics was noted in the present study 6 months after surgery – greater increase (prolongation was found in swing time (21%), this was accompanied with shortening of stance time distribution in gait cycle (Figure 2). As a result of improvement of hip abductor strength, the gait stride was 8% longer and cadence was 9% less post-surgery as compared before it. The study of McClelland et al [14] demonstrated the ability of TKA patients to increase walking speed by adjusting spatiotemporal parameters. From comfortable to fast walking the velocity in the TKA group was increased similarly to healthy controls – as a result of an increase in both stride length and cadence. 6 months after surgery no significant improvement in gait velocity was noted. Patients in the present study had lower gait velocity (0.96 pre- and 0.97 m/s post-surgery) and cadence as compared to the data of Besier et al [3] who found that PFPS subjects walked and ran with similar speed, stride length, and cadence to the control groups of males and females.

TKA patients with PFPS had no significant improvement in kinematic and kinetic characteristics of knee joint after surgery as compared pre-operatively. The tendency to improve the moment of force of knee joint flexion and extension was noted – in first maximum extension in early stance (mean increase of 85%) and in second maximum extension moment in terminal stance (increase of 23%). The study of Ouelett and Moffet [17] demonstrated that TKA patients walked with a more flexed hip in stance phase and a less flexed knee and plantarflexed ankle during early stance and had a significant decrease in extensor and flexor moments at the hip and knee throughout the gait cycle. It has been found that at the knee joint, altered tibiofemoral rotation and an increase of knee adduction during the stance phase of gait result in lateral patellar tracking and increase lateral patellofemoral joint compression [19]. It has been found that compared to healthy controls, the PFPS group had greater co-contraction of quadriceps and hamstrings during walking, even though the net knee moment was similar between groups [3].

The limitation of the present study is a small number of patients who were evaluated.

In conclusion, the study demonstrated that in TKA patients 6 months after reoperation due to PFPS the knee joint function was significantly improved – hip abduction active range of motion and isometric force were increased. At the same time the positive changes in gait with comfortable velocity were found: increase of the stride length and decrease of cadence as well as normalisation of gait cycle phases took place.

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REFERENCES

1. Arnold C. M., Warkentin K. D., Chilibeck P. D., Magnus C.R. (2010) The reliability and validity of handheld dynamometry for the measurement of lower-extremity muscle strength in older adults. J. Strength Cond. Res. 24: 815–824
2. Barton C. J., Levinger P., Menz H. B., Webster K. E. (2009) Kinematic gait characteristics associated with patellofemoral pain syndrome: A systematic review. Gait Posture. 30: 405–416
3. Besier T. F., Fredericson M., Gold G. E., Beaupré G. S., Delp S. L. (2009) Knee muscle forces during walking and running in patellofemoral pain patients and pain-free controls. J. Biomech. 42: 898–905
4. Clarcson H. M. (2005) Joint motion and function assessment. Lippincott, Williams &Wilkins, Philadelphia
5. Cooney W. P. 4th, Sierra R. J., Trousdale R. T., Pagnano M. W. (2005) Revision total knees done for extensor problems frequently require reoperation. Clin. Orthop. Relat. Res. 440: 117–121
6. Crossley K., Cowan S., Green S., McConnel J. (2001) A systematic review of physical interventions for patellofemoral pain syndrome. Clin. J. Sport Med. 11: 103–110
7. Davis R. B., Ounpuu S., Tyburski D. S., Gage J. R. (1991) A gait analysis collection and reduction technique. Hum. Mov. Sci. 10: 575–587
8. Elias J. J., Bratton D. R., Weinstein D. M., Cosgarea A. J. (2006) Comparing two estimations of the quadriceps force distribution for use during patellofemoral simulation. J. Biomech. 39: 865–872
9. Fergusson D., Hutton B., Drodge A. (2007) The epidemiology of major joint contractures: a systematic review of the literature. Clin. Orthop. Relat. Res. 456: 22–29
10. Fuchs S., Floren M., Skwara A., Tibesku C. D. (2002) Quantitative gait analysis in unconstrained total knee arthroplasty patients. Int. J. Rehabil. Res. 25: 65–70
11. Haviko T., Märtson A., Parv M. (2009) Jacques Duparc Award. 10th EFORT Congress, Vienna, Austria, 3–6 June 2009, P708

12. Kendall F. P., McCreary E. K., Provance P. G., Rodgers M. M., Romani W. A. (2005) Muscles testing and function with posture and pain. 5th edn. Lippincott Williams & Wilkins, Baltimore
13. Lee T. Q., Sandusky M. D., Adeli A., McMahon P. J. (2002) Effects of simulated vastus medialis strength variation on patellofemoral joint biomechanics in human cadaver knees. J. Rehabil. Res. Dev. 39: 429–438
14. McClelland J. A., Webster K. E., Feller J. A., Menz H. B. (2011) Knee kinematics during walking at different speeds in people who have undergone total knee replacement. Knee. 18: 151–155
15. McConnel S., Kolopack P., Davis A. M. (2001) The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): a review of its utility and measurement properties. Arthritis Rheum. 45: 453–461
16. Mollinger L. A., Steffen T, M. (1993) Knee flexion contractures in institutionalized elderly: prevalence, severity, stability, and related variables. Phys. Ther. 73: 437–446
17. Ouellet D., Moffet H. (2002) Locomotor deficits before and two months after knee arthroplasty. Arthritis Rheum. 47: 484–493
18. Parker D. A., Dunbar M. J., Rorabeck C. H. (2003) Extensor mechanism failure associated with total knee arthroplasty: prevention and management. J. Am. Acad. Orthop. Surg. 11: 238–247
19. Powers C. M. (2003) The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J. Orthop. Sports Phys. Ther. 33: 639–646
20. Scuderi G. R., Insall J. N., Scott N. W. (1994) Patellofemoral pain after total knee arthroplasty. J. Am. Acad. Orthop. Surg. 2: 239–246
21. Senavongse W., Bull A. M. J., Taylor A. R., Amis A. A. (1998) Muscle imbalance alone does affect patellar tracking: an in-vitro investigation. J. Bone. Joint Surg. Br. 80B (Suppl 3): 258
22. Sensi L., Buzzi R., Giron F., De Luca L., Aglietti P. (2011) Patellofemoral function after total knee arthroplasty: sex-related differences. J. Arthroplasty. 26: 1475–1480
23. Sierra R. J., Cooney W. P. 4th, Pagnano M. W., Trousdale R. T., Rand J. A. (2004) Reoperations after 3200 revisions TKAs: rates, etiology, and lessons learned. Clin. Orthop. Relat. Res. 425: 200–206
24. Slemenda C., Heilman D. K., Brandt K. D., Ktz B. P., Mazzuca S. A., Braunstein E. M., Byrd D. (1998) Reduced quadriceps strength relative to body weight: a risk factor for knee osteoarthritis in women. Arthritis Rheum. 41: 1951–1958

25. Tew M., Forster I. W., Wallace W. A. (1989) Effect of total knee arthroplasty on maximal flexion. Clin. Orthop. Rel. Res. 247: 168–174
26. Wilson S. A., McCann P. D., Gotlin R. S., Ramakrishnan H. K., Wootten M. E., Insall J. N. (1996) Comprehensive gait analysis in posterior-stabilized knee arthroplasty. J. Arthroplasty. 11: 359–367

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MOTIVES AND MOTIVATING LEADERS IN AEROBICS CLASSES: EXERCISE MOTIVATION AND INSTRUCTORS' LEADERSHIP CHARACTERISTICS

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ABSTRACT

The aim of this study was to investigate the motives of aerobics participants in relation to their perceived and preferred leadership behavior of aerobic instructors.

Eighty seven aerobics participants (aged between 16–59 y) completed the cross-sectional questionnaire survey. Instruments assessed participants' exercise motivation, and perceived and preferred leadership behaviour of their aerobic instructors.

We found that in aerobics participants the appearance- and health-related dimensions of exercise motivation are higher ranked than flexibility and social motives. Although aerobics participants show relatively high levels of competitive and social motives compared with general population, the highest ranked incentive for them seems to be physical fitness. Aerobics participants perceive significantly less instructors' democratic decision making, instruction, social support and positive feedback than they prefer, while they perceive significantly higher amount of autocratic decision making compared with their preference.

Key words: motivation for participation in aerobics, leadership behavior

INTRODUCTION

Since more than three decades motivation for fitness activities and factors which influence exercise participation have been a matter of special interest to researchers. Most frequently motives such as enjoyment, social interaction, positive affective responses and perceived accomplishment have emerged [5]. The aim of the present study was to investigate the role of various motivating factors in participation in aerobics. Aerobics was chosen as it provides an exercise context including personal goals in a group setting, potentially reflecting both individual and social motivational factors.

Participation motives represent diverse goals for taking part in a particular domain of behaviour. Often motivation for participation in both sport and exercise has been explained in terms of the Self-Determination Theory (SDT) [8, 9]. According to the SDT, the regulation towards exercise participation can be amotivated, extrinsically motivated or intrinsically motivated. Research reveals that intrinsic motivation represents autonomous behavioural regulation which is associated with greater continuous participation in physical activity [11, 12, 21]. In general, intrinsic motivation reflects engaging in the activity for its own sake. An intrinsically motivated person considers the physical activity inherently enjoyable, interesting, and challenging [8, 9]. Still, findings are less clear in aerobics setting. Frederick and Shaw [10] found that appearance-related motives dominate in aerobics participation. Importantly, Laverie [15] determined 6 distinctive motives for participation in aerobics: atmosphere of an aerobics class, physical and psychological benefits, social ties related to aerobics, social comparisons, obsession with aerobics, and feelings associated with doing aerobics.

In sport settings, besides motivational characteristics, specific coaching behaviors also have the potential to influence cognitive and behavioral processes in athletes [5, 6]. Over the past decades the most extensively studied framework for explanation of coaches' leader behavior is the Multidimensional Model of Leadership (MML) [4]. This model proposes that leader behavior can influence group performance and member satisfaction. Specifically, it suggests that three aspects of leader behavior need to be in congruence to achieve effective group performance and member satisfaction. First, *required* behavior (what is needed for a particular situation) is prescribed by situational and member characteristics such as goals, structure, group task, norms etc. Second, *preferred* behavior (expected by the athletes) originates from both situational and member characteristics, e.g. goals, abilities, personality, and attitudes toward authority. Third, *perceived* behavior (the coach's behavior as perceived by the athletes) is determined by the characteristics of the leader (personality, ability, experience, and decision making style), but also by required and preferred leader behavior. The leader, as suggested by the MML, may alter his or her behavior to the requirements of the situation and the preferences of the members in order to increase congruence between those three aspects of leadership behavior.

There is evidence that smaller discrepancy between perceived and preferred leadership behavior has a significant positive effect on motivation [1]. Particularly, more frequent training and instructional guidance and infrequent use of autocratic decision style increase the satisfaction of members. Also, it has been found that most of leader behavior has a positive impact on member satisfaction if preferred and perceived leader behavior is concordant [2, 19]. However, a recent study in Estonia demonstrated that individual athletes perceive less training and instruction, democratic decision making, social support, and positive feedback from their coaches than they prefer. In contrast, they reported higher amount of perceived autocratic decision making compared to what they prefer [20].

Although there is a large body of research in exercise motivation, only a few studies have been conducted to explore (motivational) features of exercise instructor's behaviour. It has been found that intrinsic motivation and supportive leadership have motivating effect on women's exercises participation [16]. Similarly, in female exercisers socially enriched leadership is associated with greater exercise enjoyment [3]. In Estonia, aerobics participants have demonstrated higher intrinsic motivation compared with gym and indoor rowing participants [14], while instructional and motivational behavior of instructor is positively related to intrinsic motivation [17].

In this study we explored exercise motives for participation in aerobics. First, we assessed exercise motives of aerobics participants and compared them with exercise motives in a representative Estonian female sample. Second, in order to find which exercise motives are more salient than others in aerobics participants, we estimated relative weight of distinctive exercise motives. Third, we assessed perceptions and preferences for instructor's leadership behavior and their relations to exercise motives in aerobics participants.

MATERIALS AND METHODS

Participants and procedure

Data were collected from cross-sectional survey in 7 exercise clubs. Inclusion criterion for volunteers was participation in a formal aerobics exercise group lead by an instructor. One of the authors distributed the questionnaires personally to each participant and explained the general purpose of the study. Participants returned the completed questionnaires within 2 weeks.

Out of 272 delivered questionnaires 94 (34.6%) were returned. Due to missing values 7 questionnaires were omitted from analysis. Therefore, data from 87 aerobics participants (aged between 16–59 years, mean=26.1, SD=9.0) were included in the study.

Measures

To measure characteristics of personal exercise motives and instructor's leadership behaviour, following questionnaires were used:

1. *Modified Estonian Exercise Motivation Questionnaire-2*, (EMQ-2EM [18]; [original 13]). EMQ-2M consists of 37 items. Subscale scores were computed for 7 different exercise motives: Competition (e.g. *I exercise to compare my abilities with other peoples'*), Health (*I exercise because I want to maintain good health*), Appearance (*I exercise to improve my appearance*), Social Recognition (*I exercise to have fun being active with other people*), Fun and Relaxation (*I exercise because I find exercising satisfying in and of itself*), Physical Fitness (*I exercise to build up my strength*), and Flexibility (*I exercise to stay/become flexible*). The response format was to indicate how much each statement is true for the participant from *not at all true for me* (0) to *very true for me* (5).

2. *Estonian Leadership Scale for Sport* (E-LSS [20]; [original 7]). LSS is a sport-specific questionnaire designed to assess 5 distinctive dimensions of leadership behaviour. Specifically, LSS is designed to assess (a) *perceived* leadership behaviour and (b) *preferred* leadership behaviour.

2.1. The Perceived Leadership Behaviour (PercLB) form requires participants to estimate the frequency (never, seldom, occasionally, often, always) of specific behaviours. Forty items represent the 5 subscales: Training and Instruction (*My coach instructs every person individually in the skills of the sport*), Democratic Behaviour (*My* *coach lets the group set its own goals*), Autocratic Bahaviour (*My coach speaks in a manner not to be questioned*), Social Support (*My coach does personal favors for the exercisers*), and Positive Feedback (*My coach compliments a person for her performance in front of others*).

2.2. The Preferred Leadership Behavior (PrefLB) form requires indicating to what extend the participant prefers to experience those five behaviors.

Statistical analysis

Statistical analyses were performed using the STATISTICA (version 8.0) software. Results are expressed as mean values (mean), standard deviations (SD), and sample size (N). The one-sample t-tests and Student's t-test were performed to contrast mean values. Pearson's correlation coefficients indicate connections between variables. An alpha level of .05 was used for all statistical tests.

To compare the exercise motives of aerobics participants with the exercise motives of a representative Estonian female sample, the subscale scores of the EMI-2EM were standardized by adding up the raw scores of each subscale, then dividing this sum by the number of items in that subscale, and multiplying it by five [18].

RESULTS

Descriptive statistics

Table 1 and 2 represent the descriptive statistics of EMI-2EM, PercLB, and PrefLBH. First, the exercise motives of aerobic participants were compared with the respective motives of a representative Estonian female sample consisting of 931 females between 18 and 55 years [18]. To illustrate the exercise motives of aerobics participants in relation to Estonian female sample, the T-scores were calculated (Table 1).

Table 1. Descriptive statistics of *Modified Estonian Exercise Motivation Questionnaire-2* and the T-score values of aerobics participants in relation to Estonian female sample (n=87).

Subscale	mean	SD	T-score
Competition	9.36	4.9	58.2
Health	19.23	4.5	59.8
Appearance	18.19	6.6	83.2
Social Recognition	8.68	6.3	74.4
Fun & Relaxation	18.48	4.9	62.8
Physical Fitness	20.01	4.5	73.0
Flexibility	15.90	6.8	72.3

T-scores are calculated in relation to the representative Estonian female sample n=931 by Matsi [18].

Table 2. Descriptive statistics of the *Perceived Leadership Behavior* (PercLB) and *Preferred Leadership Behavior* (PrefLB) (n=87).

	PercLB		PrefLB	
Subscale	**mean**	**SD**	**mean**	**SD**
Training and Instruction	3.39	0.7	3.62	0.6
Democratic Behaviour	3.18	0.6	3.33	0.6
Autocratic Behaviour	2.00	0.6	1.86	0.5
Social Support	2.22	0.5	2.34	0.5
Positive Feedback	3.20	0.9	3.33	0.8

Further, one sample t-tests indicated motivational deviation of aerobics participants from Estonian female sample. We found that aerobics participants showed significantly higher Competition motive (9.36± 4.9) compared with the Estonian female sample (5.31±5.4), t[1016] = 6.68, p < .00001. The same effect was found for Fun and Relaxation motive (18.48±4.9), Physical Fitness motive (20.10±4.5) and Flexibility motive (15.90±6.8) compared with the Estonian female sample (15.18±5.7), t[1016]=4.53, p<0.0001; 15.00±6.7; t[1016]= 6.80, p<0.00001; and (12.46±8.09), t[1016]=5.06, p<0.00001, respectively.

Relative saliency of exercise motives

In order to assess the relative saliency of distinctive exercise motives, t-tests were conducted. Table 3 represents the *t*-statistics illustrating differences in mean scores of exercise motives. In general, Competition and Social Recognition motives showed the lowest mean scores in aerobics participants (see Table 3).

Table 3. Comparision of the mean scores of exercise motives (EMI-2EM). Differences between the mean values are represented as *t*-scores, t(86) (n=87).

	Health	**Appearance**	**Social Recognition**	**Fun & Relaxation**	**Physical Fitness**	**Flexibility**
Subscale (mean)	**(19.2)**	**(18.2)**	**(8.7)**	**(18.5)**	**(20.0)**	**(15.9)**
Competition (9.4)	**15.71****	**11.09****	1.01	**15.62****	**20.89****	**8.59****
Health		1.29	**13.72****	1.37	1.49	**4.54****
Appearance			**10.60****	0.34	**2.24**	**2.20**
Social Recognition				**14.75****	**15.16****	**7.66****
Fun & Relaxation					**2.60**	**3.28***
Physical Fitness						**6.47****

Statistically significant t-statistics are printed in bold $p<0.05$, *$p<0.01$, **$p<0.001$.

Next, we divided the sample into two subgroups based on the score of Fun and Relaxation motive. The aim was to search for further explanations for higher levels of exercise motivation in comparison to the representative Estonian sample. The rationale behind this was to differentiate participants based on the exercise motive potentially highly representative for intrinsic motivation. The cut-off score was 3.5 points. Group differences between low and high Fun and Relaxation motive groups are presented in Table 4.

Tabel 4. Comparison of exercise motives between subgroups characterized by low (<3.5) and high (>3.5) Fun and Relaxation motive.

	Low F&R		High F&R			
Subscale	**mean**	**SD**	**mean**	**SD**	**t**	**p**
Competition	**1.39**	**0.8**	**2.13**	**1.0**	**3.541**	**0.000650**
Health	**3.43**	**1.0**	**4.06**	**0.8**	**3.245**	**0.001683**
Appearance	3.54	1.2	3.69	1.4	0.504	0.615545
Social Recognition	**1.26**	**1.2**	**1.99**	**1.2**	**2.683**	**0.008761**
Physical Fitness	**3.64**	**1.1**	**4.20**	**0.7**	**2.866**	**0.005242**
Flexibility	2.81	1.4	3.37	1.3	1.819	0.072469

Low F&R – subgroup of participants low in Fun and Relaxation motive, n=30 (Fun and Relaxation mean=2.55, SD=1.4), High F&R – subgroup of participants high in Fun and Relaxation motive, n=57 (Fun and Relaxation mean=4.30, SD=1.8); t statistics and Alpha values are presented.

Relations between instructor's leadership behavior and exercise motives

Correlation analysis estimated relationships between perceived or performed leadership behavior of aerobics instructors and exercise motives. Interestingly, Competition motive was negatively related to both perceived Democratic and Autocratic Behavior ($r=-0.22$, $p<0.05$) while it was positively related to preferred Democratic ($r=0.21$, $p<0.05$) and Autocratic Behavior ($r=0.32$, $p<0.05$). In addition, participants higher in Physical Fitness motive perceived less Positive Feedback from instructors ($r=-0.22$, $p<0.05$). Further, higher Flexibility motive was related to lower frequency of perceived Autocratic Behavior ($r=-0.21$, $p<0.05$) and higher preferred Autocratic Behavior ($r=0.26$, $p<0.05$). Individuals with higher Appearance motive would prefer to get more Training and Instruction ($r0=0.29$) and Democratic Behavior ($r0=0.22$, $p<0.05$) from their instructors.

Congruence between perceived and preferred leadership behavior in aerobic instructors

Finally, we were interested in congruence between perceived and preferred leadership behavior of aerobics instructors. In order to estimate potential discrepancies we calculated proportional difference between perceived and preferred behavior. Specifically, we calculated ratios of perceived behavior to preferred behavior (Figure 1). Results indicated that participants perceived more Autocratic Behavior than preferred (110.6%). In contrast, participants reported less perceived Training and Instruction (94.3%), Democratic Behavior (97.0%), Social Support (96.2%), and Positive Feedback (98.7%) in relation to preferred leadership behaviors. However, t-tests for single sample suggest that discrepancies were statistically significant only for Training and Instruction ($t[86]=-3.77$, $p<0.001$) and Autocratic Behavior ($t[86]=3.39$, $p<0.01$).

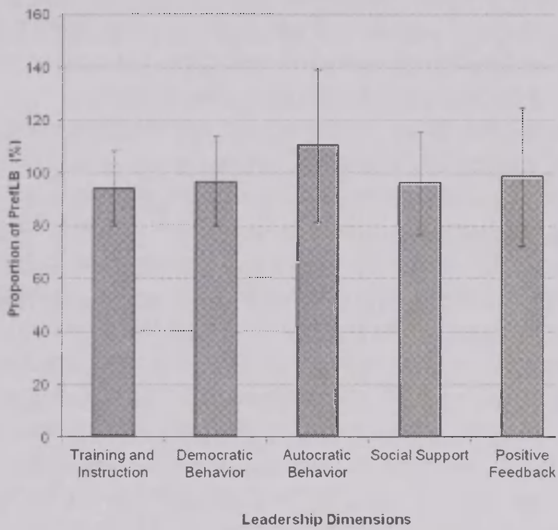

Figure 1. Congruence between perceived and preferred leadership behavior of aerobics instructors presented as proportional difference between perceived and preferred behavior (ratios of perceived behavior over preferred behavior). Mean values and standard deviations are presented.

DISCUSSION

In this study we first aimed to explore exercise motives of individuals regularly participating in aerobics classes. Secondly, we estimated how aerobics participants perceive the behavior of their instructors and how they would prefer instructors to behave. Thirdly, we were interested in relations between motives for aerobics participation, specific leadership behaviors demonstrated by aerobics instructors and preferences for instructor's behavior.

Previous studies in samples of aerobics exercisers reveal rather controversial results [3, 10, 14, 15, 17]. Therefore we decided to compare a female sample of aerobics exercisers to a relatively large representative sample of Estonian females and to estimate the saliency of distinctive motives. Our results suggest that aerobics exercisers show higher levels of enjoyment related motives as well as motives related to competing and social evaluation, and increasing one's physical fitness, compared to the general female population. However, individuals regularly participating in aerobics classes rate fitness- and health-related motives significantly higher than competitive and social motives. Fun and Relaxation motive, reflecting enjoyment of exercise, shows the third-highest rank for aerobics participants.

We propose that these results could be interpreted in terms of enjoyment of exercising. About 2/3 of our participants demonstrated rather high level of fun and relaxation motive. Previous results in the general Estonian female population (including sedentary individuals) suggest that only fun and relaxation motive is systematically related to actual physical activity [18]. In current study we found most exercise motives to be elevated in the subgroup of high level fun and relaxation motive, compared with subgroup of low fun and relaxation motivation. In terms of the SDT we propose that fun and relaxation motives reflect enjoyment of exercise. Experience of fun and enjoyment represent intrinsic motivation, which is a strong predictor of regular physical activity [11, 12, 21]. A rough suggested explanation would be that strong intrinsic regulation supports also high levels of motives related to social comparison and social recognition. These motives could easily align with intrinsic need for relatedness [8, 9]. Physical fitness motive (also higher in the subgroup of high fun and relaxation motivation) might derive from the intrinsic need for perceived competence. In contrast, the appearance motive which definitely reflects extrinsic motivation did not differentiate between the subgroups of high and low fun and relaxation motivation. Thus, although aerobics participants show relatively high levels of competitive and social motives compared with general population, the highest ranked incentive for them seems to be physical fitness. We suggest that in future studies the role of intrinsic motivation should be carefully investigated in aerobics settings.

Although we found that aerobic exercisers are driven by motive to compete more frequently than general population, this motive is relatively low in comparison with most other motives in the sample of aerobics participants. Most likely, this reflects the nature of aerobics classes, where no explicit competition occurs. Highly competitive individuals probably seek to participate in competitive sports. This explanation is supported by the fact that we found no systematic relationship between fun and relaxation motive and competition motive. Notably, the motive of physical fitness was not only higher in aerobic exercisers than in the rest of the population, but it appeared also to be the highest ranked exercise motive in aerobic participants.

Our findings also shed light on the perception and preference of instructors' leadership behavior. We found a negative relationship between competitive motive and both perceived autocratic and democratic behaviour. Thus, individuals higher in competitive motive report their aerobics instructors to show less democratic and autocratic decision making during exercise classes. In addition, since competitive motivation was positively related to prefer democratic and autocratic decision making, it seems that more competitive individuals would prefer their instructors to ask explicitly for participants' opinion and/or make more resolute decisions. Furthermore, discrepancies between the amount of perceived and preferred leadership behaviors indicate that aerobics exercisers with high competitive motive perceive less decision making behaviors than they would prefer experience in their exercise classes.

Generally, we can conclude that high levels of exercise motives predominantly reflecting intrinsic behavior regulation differentiate aerobics exercisers from general population. Exercise motives are systematically related to perceived and preferred leadership behavior of aerobics instructors. Further empirical research is required to find causal relationships between exercise motives and leadership behaviors that support exercise motivation.

REFERENCES

1. Amorose A. J., Horn, D. S. (2000) Intrinsic motivation: Relationships with collegiate athletes gender, scholarship status and perceptions of their coaches behavior. J. Sport Exerc. Psychol. 22: 63–84
2. Andrew D. (2009) The impact of leadership behavior on satisfaction of college tennis payers: a test of the leadership behavior congruency hypothesis of the Multidimensional Model of Leadership. J. Sport Behav. 32: 261–277
3. Bray S. R., Millen J. A., Eidsness J., Leuzinger, C. (2005) The effects of leadership style and exercise program choreography on enjoyment and intentions to exercise. Psychol. Sport Exerc. 6: 415–425
4. Chelladurai P. (1978) A contingency model of leadership in athletics. Unpublished doctoral dissertation. Department of Management Sciences, University of Waterloo, Canada
5. Chelladurai P. (1990) Leadership in sports: A review. Int. J. Sport Psychol. 21: 328–354
6. Chelladurai P. (1993) Leadership. In: Handbook on research on sport psychology, R. N. Singer, M. Murphy, L. K. Tennant (eds). New York: McMillan. 647–671
7. Chelladurai P., Saleh S. D. (1980) Dimensions of leader behavior in sports. Can. J. Appl. Sport Sci. 3: 85–92
8. Deci E. L., Ryan R. M. (1985) Intrinsic motivation and self-determination in human behaviour. New York: Plenum Press
9. Deci E. L., Ryan R. M. (2000) The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. Psychol. Inquiry. 11: 227–268
10. Frederick C. J., Shaw S. M. (1995) Body image as a leisure constraint. Examining the experience of aerobic exercise classes for young women. Leisure Sci. 17: 57–73
11. Gillison F. B., Standage M., Skevington S. M. (2006) Relationships among adolescents’ weight perceptions, exercise goals, exercise motivation, quality of life and leisure-time exercise behaviour: a self-determination theory approach. Health Educ. Res. 21: 836–847
12. Ingledew D. K., Markland D. (2008) The role of motives in exercise participation. Psychol. Health. 23: 807–828
13. Ingledew D., Markland D., Medley A. (1998) Exercise Motives and Stages of Change. J. Health Psychol. 3: 477–489
14. Klaos, H. (2007) Harrastussportlase motivatsioon, enese-esitlemine ja psühholoogilised vajadused. Unpublished master thesis. Faculty of Sport and Exercise Sciences, University of Tartu, Estonia

15. Laverie D. (1998) Motivation for ongoing participation in a fitness activity. Leisure Sci. 20: 277–303
16. Lloyd K. M., Little D. E. (2010) Keeping women active: An examination of the impacts of self-efficacy, intrinsic motivation, and leadership on women's persistence in physical activity. Women Health. 50: 652–669
17. Lukner K. (2007) Aeroobikaharrastajate treeningumotivatsioon ja hinnang treeneri käitumisele. Unpublished master thesis. Faculty of Sport and Exercise Sciences, University of Tartu, Estonia
18. Matsi J. (2009) Eesti 18–50 aastaste naiste enese raporteeritud vaba aja kehalise aktiivsuse motivatsioon ja takistused. Unpublished master thesis. Institute of Psychology, University of Tartu, Estonia
19. Riemer H. A., Chelladurai P. (1995) Leadership and Satisfaction in Athletics. J. Sport Exerc. Psychol. 17: 276–293
20. Sirge K. (2008) Spordi Eestvedamise Küsimustiku adapteerimine Eesti individuaalsportlaste ja treenerite valimil. Unpublished master thesis. Faculty of Sport and Exercise Sciences, University of Tartu, Estonia
21. Standage M., Sebire S. J., Loney T. (2008) Does exercise motivation predict engagement in objectively assessed bouts of moderate-intensity exercise?: a Self-Determination Theory perspective. J. Sport Exerc. Psychol. 30: 337–352

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EXERCISE-INDUCED CHANGES IN BODY FAT, UPPER LEG SKELETAL MUSCLE AREA, BMI AND BODY WEIGHT IN OVERWEIGHT PEOPLE WITH RISK OF DEVELOPING TYPE 2 DIABETES

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ABSTRACT

The study compared effects of maximal resistance training (MRT) versus endurance resistance training (ERT) in overweight people at risk of developing Type 2 Diabetes. Dependent variables included changes in body fat %, upper leg skeletal muscle area (left + right), BMI and body weight pre-to post intervention. Eighteen individuals, 33- 69 years of age, were randomly assigned to one of two groups. Group 1 engaged in MRT three days/week over a four month period while members of Group 2 acted as controls. Later, Group 2 engaged in ERT three days/week over a four month period and the members acted as their own controls. Both interventions consisted of eight exercises. Pre- to post changes were significant for MRT with a reduction in BMI (p=0.013) and body weight (p=0.010), while percentage of body fat was significantly reduced (p=0.009) and skeletal muscle area increased (p=0.021) with ERT. The results support both approaches as interventions in primary prevention of obesity and consequently in reducing risk of Type 2 Diabetes.

Key words: BMI, resistance training, impaired glucose tolerance, percentage of body fat, skeletal muscle.

INTRODUCTION

Impaired glucose tolerance (IGT) and Type 2 Diabetes, as well as hypertension and overweight, are major challenges for current public health management [6, 23, 33]. Many adults with diabetes are overweight and more than half of adults with diabetes are obese [9]. Obesity is associated with cardiovascular risk factors such as increased blood glucose [1]. A lifestyle involving limited physical activity seems to be one of the most important reasons for the development of obesity [8, 23, 27]. Physical inactivity and increased body weight are expected to increase the prevalence of Type 2 Diabetes in Europe from 3.5% to 4.75% over the next 25 years [34]. At the same time, obesity is a serious health concern among more than 300 million people worldwide, and its prevalence increased by 50 % in only seven years [32].

Resistance training can lead to changes in body fat, skeletal muscle, body mass index (BMI) and body weight as it is known to increase the volume of muscle and hence overall muscle mass. Maximal resistance training (MRT) [5] aims to build increased muscle mass under anaerobic exercise conditions. Optimal intensities during resistance training are 60–80% of 1RM. Conventional aerobic endurance resistance programs include multiple bouts of low work-load exercises at 45–65% of 1RM training, with intervals of pauses to slow down the heart-rate and allow muscle cells to be refilled with oxygen.

Lifestyle interventions appear to be effective in the prevention of Type 2 Diabetes among people with IGT. Results from a recent study suggested that screening for Type 2 Diabetes and IGT, with appropriate intervention for those with IGT, in an above average risk population aged 45, is cost effective [13]. Several studies have reported improvements in glucose tolerance with resistance training [16, 28, 29], whereas others have not [18, 36]. It is still unclear to what extent this type of intervention has beneficial effects on metabolism in individuals with normal glucose tolerance (NGT) [25]. Resistance training reduces total body fat mass in men and women, independent of dietary caloric restriction [7, 24]. Resistance training may reduce visceral adipose tissue in older men and women. In a review study, Gordon et al. [14] claimed that supervised resistance training improves glycaemic control and insulin sensitivity in adults with Type 2 Diabetes. However, further research is needed to explore the mechanism(s) behind glucose tolerance improvements following resistance training, and to determine the optimal frequency, intensity and duration of such training. A recent study by Hansen et al. [15] concluded that maximal, as well as endurance resistance training (ERT), caused a reduction in insulin resistance in individuals at risk of developing Type 2 Diabetes. Lifestyle interventions seem to be at least as effective as drug treatment [12].

The development of obesity is associated with a worsening of blood glucose and increased risk of other cardiovascular factors [1]. Results from the "Look AHEAD trial" showed that weight loss in patients with diabetes improved glycolic control, reduced blood pressure and improved blood lipids [20]. Observational studies also support a likely link between weight loss and reduced mortality in people with Diabetes [1].

Active men with normal and overweight BMIs appear to face fewer health risks than their inactive counterparts. Elevated BMI is a key driver of diabetes risk, with relatively modest attenuation with activity. However, BMI and physical inactivity are independent risk factors in the development of Type 2 Diabetes, although the effects of the combination of these two factors are unclear [17]. One study reported a greater risk of Diabetes both for physically active and inactive overweight and obese participants than in active individuals with normal weight. Analyses of the combination of level of physical activity and BMI score state that adiposity, as associated with an above normal BMI, is a critical determinant of Diabetes [30]. A prospective study by Siegel et al. [26] reported that normal and overweight BMIs in men, who were active, were associated with a reduced risk of Diabetes in comparison with their inactive controls. There was no significant difference in Diabetes risk (incidence of Diabetes, hazard ratios (HRs)) between highly active versus highly inactive men with obesity. This lack of difference suggests that the increase in BMI may be one important factor in the risk of Diabetes, even though inactivity alone may not be an important predisposing factor. Hansen et al. [15] suggest that resistance training improves both glycemic control and insulin sensitivity. Potential mechanisms behind this are the physiological changes induced by resistance training. Other determinants are discrete pathways to provide additive insulin signaling benefits [3]. Most people with Diabetes and IGT are overweight or obese. Such conditions may provoke increased motivation for compliance to prevent the development of Diabetes.

Interventions conducted by general practitioners seem to be limited, indicating that intervention strategies should specifically be tailored to the individual, assisted by training practitioners [22].The aim of the present study is to compare the effects of maximal resistance training and endurance resistance training in overweight people at risk of developing Type 2 Diabetes. Dependent variables included changes in body fat, upper leg skeletal muscle area (left + right), BMI and body weight pre-to post intervention.

MATERIAL AND METHODS

Participants

Eighteen perticipants, who were classified as IGT in a large-scale public health screening study in Norway in 2004 [21], according to standards set by theWHO [31], volunteered for this study. The sample consisted of 4 men and 14 women. The participants were randomized into two groups with 9 individuals in each. To accommodate gender differences, two men were randomized into each group. (Group 1: Males=2; mean age=47.5 years, Females=7; mean age=46.5 years. Group 2: Males=2, mean age=60.5 years, Females=7, mean age= 44.4 years. Overall age range 33–69 years). Both groups fulfilled the criterion for BMI, and were overweight (Group 1, mean-value 28.55 kg/m^2, SD=4.3, Group 2, mean value 27.17 kg/m^2, SD=4.1). During the second intervention, consisting of conventional endurance ERT (Group 2), there were two drop-outs. Written informed consent was obtained from each of the study participants in accordance with the Helsinki Declaration [2]. The study was approved by the Regional Committee for Ethics in Medical Research (Ref. No. 4.2006.2549).

Procedures

Participants in Group 1 were involved in a lifestyle intervention program for four months. This program focused on MRT (Bernstein inverted pyramid system [4]), 3 days/week (5 x 3–4, 60–85% 1 RM) [5]. Members of Group 2 acted as controls and Group 2 was put on hold until Group 1 had completed the prescribed training program. Group 2 started the life style intervention program, which was composed of conventional ERT 3 days/week (3 x 12–15, 45–65% 1 RM), following the initial four month wait [5]. Both groups performed the intervention at a fitness center. The first three weeks focused on providing instructions on how to properly perform assigned exercises. The guided interventions consisted of eight exercises for the whole body: (1) total abdominal, (2) lower back, (3) press for thighs, (4) leg press, (5) chest press, (6) arm press, extension for triceps, (7) pull down for upper back and (8) arm curl for biceps. The principles behind the heavy muscle strength-promotion training were maximal intensity with a load that was lifted 4 repetitions to exhaustion. Then, a reduced load was permitted for every new set of 4 repetitions without breaks in between, continuing until the muscles were exhausted [4]. Before and after the resistance exercises, the individual walked for 10 minutes on a treadmill to warm up, and walked 10 minutes after the resistance training to cool down. ERT included intensity training, with a load that permitted twelve – fifteen repetitions, in sets of three, with a break of 1.5–2 minutes between sets. Similar to the procedure for Group 1, participants in Group 2 walked for10 minutes to warm up on a treadmill before resistance exercising, and walked an additional 10 minutes to cool down after resistance exercises.

Measures

Clinical measures were taken with the participants wearing undergarments without shoes; height was rounded off to the nearest 1 cm and weight to the nearest 0.5 kg, and these measures were used for the BMI algorithm (kg/m^2). The WHO categories for BMI were used [32]: Normal weight (18.5 – 24), overweight (25 – 29), and obese ($\geq$30). Furthermore, waist circumference was measured horizontally at the height of the umbilicus to the nearest 1 cm when the participant was standing with arms hanging relaxed. Four skinfold measures on biceps, triceps, subscapularis and suprailiac together with measured waist circumference, combined with age and gender were used in the algorithm to calculate the total body fat index [10]. Upper leg skeletal muscle mass was estimated by magnetic resonance imaging (MRI) technology.

Method of choice for scanning

Measurements were performed on a 1.5 T GE Signa HDX MRI scan with software version 14.0.M5. The measurement protocol was based on T1 weighted FSE (Fast Spin Ecco) MRI in order to be able to make an image suitable for measuring the parameters of interest. This was found sufficient to clearly differentiate between muscle mass, subcutaneous adipose and bone tissue.

For the upper leg the following technical parameters were used: Freguency 512; Phase 256; NEX (Number of Excitations) 20; ETL (Ecco Train Length) 3; FOV (Field of view) 46; slice thickness 8,0 mm, spacing between slices 2,0 mm; TR (Repetition Time) 340 msec; TE (Ecco Time) min-full; BW (Band With) 15.63.

The protocol was designed to produce imaging uptake at the same location for all participants and at the same location when carrying out pre- and post- measurements. Estimates were made 24 cm proximal to the knee joint. This seemed to be the most suitable area as it included all muscle groups of interest.

The MRI provided a transverse picture through the upper leg. Based on these images, we used a software toll (from SECTRA RIS) with a marker of region of interest to delineate the muscle tissue, subcutaneous adipose tissue and bone. This approach excluded the greater neurovascular bundles of the lower extremities. The results were given as square mm (mm^2), and subtraction was used to determine the area of each tissue compartment [19].

Statistical analysis

The SPSS 17.0 statistical package was applied in all statistical analyses (SPSS Inc, Chicago, Ill, USA). T-tests were carried out to assess homogeneity between the groups. Potential differences were investigated between pre- and post- assessments, and between groups by repeated measures analysis of variance (ANOVA) with one within (pre–post) and one between (Group 1 vs. Group 2) factors. T-tests for dependent samples were used to assess changes from pre- to post intervention in Groups 1 and 2. T-test statistics were assessed to arrive at a main effect for each exercise intervention. Furthermore, measures of net mean changes were compared to determine any superiority.

RESULTS

Means and standard deviations are given for each group at baseline (Table 1). Scores are given for percentage of body fat, upper leg skeletal muscle area (left + right), BMI and body weight. The study groups fulfilled the criterion for an overweight BMI (Group 1, mean-value 28.55 kg/m^2, SD=4.3, Group 2, mean-value 27.17 kg/m^2, SD=4.1). T-tests showed homogenity between the groups with no signifcant differences in mean value of the dependent variables.

Table 1. Means and standard deviations (±SD), t-scores and p-values for groups of homogeneous dependent variables (percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight at baseline (n= 18).

	Group 1 (n=9)		Group 2 (n=9)			
Variables	**Mean**	**SD**	**Mean**	**SD**	**T-score**	**p-value (2-tailed)**
Percentage body fat (%)	39.7	4.9	36.7	5.5	1.16	0.260
Skeletal muscle area (mm)	25730	3811	24473	5238	0.582	0.569
BMI (kg/m^2)	28.55	4.3	27.20	4.2	0.69	0.498
Body weight (kg)	76.8	11.6	78.2	16.9	-0.21	0.835

Means and standard deviations in percentage body fat, upper leg skeletal muscle area, BMI and body weight before and after four months of MRT for Group 1 are presented in Table 2. T-scores and p-values are given for pre to post-differences. A significant decrease in weight was seen from pre to post-intervention (p=0.010). The decrease was accompanied by a significant increase in BMI from pre to post-intervention (p=0.013).

Table 2. Means and standard deviations (±SD) of percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight before and after four months of MRT in a group of overweight individuals (n=9) at risk of Type 2 Diabetes. T-scores and p-values are given for pre- and post-measures.

Variables	**Pre mean**	**SD**	**Post mean**	**SD**	**T-Score**	**p-value**
Percentage body fat (%)	39.7	4.9	38.6	5.0	2.17	n.s.
Skeletal muscle area (mm)	25730	3812	25800	3408	-0.42	n.s.
BMI (kg/m^2)	28.55	4.3	27.40	3.9	3.20	0.013
Body weight (kg)	76.8	11.6	74.0	11.9	3.37	0.010

n.s.=not significant

Means and standard deviations in percentage of body fat, upper leg skeletal muscle area, BMI and body weight before and after four months of ERT are presented for Group 2 in Table 3. T-scores and p-values are given for pre- to post-differences. A significant decrease in percentage of body fat was seen from pre to post intervention (p=0.009). The decrease was contrasted with a significant increase in sceletal muscle area from pre to post intervention (p=0.021). No significant change was found for BMI and body weight, which might indicate that body mass shifted from fat to skeletal muscle mass due to the four months of ERT.

Table 3. Means and standard deviations (SD) of percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight before and after four months of endurance resistance training in a group of overweight individuals (n=7) at risk of Type 2 Diabetes. T-scores and p-values are given for pre- and post-measures.

	Pre		**Post**			
Variables	**Mean**	**SD**	**Mean**	**SD**	**T-score**	**p-value**
Presentage body fat (%)	38.01	6.09	36.30	6.14	3.82	0.009
Skeletal muscle area (mm)	25420	5697	26290	5805	3.12	0.021
BMI (kg/m^2)	28.0	4.1	27.6	4.8	0.95	n.s.
Body weight (kg)	82.7	15.1	83.6	16.1	1.53	n.s.

n.s.=not significant

Results from the two-way repeated ANOVAs stated that F-scores for overall effects of the time factor were significant for BMI and body weight due to reductions from pre to post intervention (Table 4). F-scores for overall differences between groups were not significant. However, the group-by-time interaction was significant for percentage of body fat, BMI as well as body weight (p<0.003, 0.011 and 0.01, respectively) due to relatively marked reductions in all three measures only in the maximal resistance intervention group (Group 1).

Table 4. F-scores and p-values for effects of maximal resistance training upon change in percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight from pre- to post-intervention (Time T, Group, G), compared with pre- and post-values in a waitinglist control group (n=18).

	Time (T)		**Group (G)**		**T x G**	
Variables	**F-score**	**p-value**	**F-score**	**p-values**	**F-score**	**p-values**
Presentage body fat (%)	0.61	n.s.	0.39	n.s.	12.64	0.003
Skeletal muscle area (mm)	0.07	n.s.	0.36	n.s.	0.05	n.s.
BMI (kg/m^2)	7.70	0.014	0.17	n.s.	8.24	0.011
Body weight (kg)	8.07	0.012	0.18	n.s.	8.47	0.01

n.s.=not significant

T-test statistics were assessed to arrive at a main effect for each exercise intervention (Table 5). Measures of net mean changes were compared to determine any superiority and to compare the mean change for each dependent variable. The comparison showed that there were no significant mean changes for the variables, except for weight (p=0.004), thus indicating that there was only a partial superiority of one intervention to the other.

Table 5. Compared net Mean differences, t-scores and p-values of maximal and endurance resistance training for percentage of body fat, upper leg skeletal muscle area (left + right), body mass index (BMI), and body weight (n=16, Group 1: 9, Group 2: 7).

Variables	**Mean difference**	**t-score**	**p-value**
Presentage body fat (%)	0.641	0.955	0.356
Skeletal muscle area (mm)	-408.05	-1.756	0.101
BMI (kg/m^2)	-0.757	-1.510	0.153
Body weight (kg)	-3.684	-3.431	0.004

DISCUSSION

The findings indicate that MRT is somewhat superior to ERT in reducing body weight and BMI. Moreover, ERT appeared to be more efficient than MRT for reducing body fat and increasing skeletal muscle. This pattern of changes indicates that overall body mass shifted from fat to skeletal muscle mass due to the four months of ERT. One could therefore argue that the results encourage the use of both types of resistance training despite the significant effect upon increase in skeletal muscle area only from ERT.

Reduction of BMI and related weight loss are associated with improved glycolic control, reduced blood pressure, and improved blood lipids. All these changes reduce the risk of developing Type 2 Diabetes [11]. The present findings add further support to the review study by Anderson et al. [1] who concluded that weight management appears to be the most important therapeutic task for people with Type 2 Diabetes. Resistance training appears to significantly induce these changes. However, in the present study, weight and BMI reductions following ERT were not significant. The reason for this is probably that the increase in skeletal muscle area compensated for the loss of body fat. These findings, together with those reported by Braith and Stewart [7], show that training reduced total body fat in men and women, independent of dietary caloric restrictions.

A recent systematic review [35] identified seven studies on the effects of multi-component lifestyle interventions in people with IGT. The interventions included exercise, diet and weight loss goals. Only one study included a structured exercise training intervention. Four studies used the incidence of Diabetes over the course of the study as an outcome measure. A reduction in Diabetes risk by approximately 50 % (range 42–63 %) was reported in these four studies despite the fact that only small changes in physical activity were achieved. Therefore, the reduced risk of Diabetes was most likely attributable to factors other than physical activity. In this way, the contribution of physical activity, independent of dietary changes and weight loss, in the prevention of Type 2 Diabetes in people with symptoms associated with pre-diabetes, is still equivocal. In relation to obesity treatment, the present study furthers our understanding of resistance training as a tool for health care providers in this field, particularly given that most people with Diabetes and IGT are overweight or obese. The present findings encourage recommending MRT as well as ERT for overweight individuals as well as individuals perhaps at risk of developing Type 2 Diabetes.

In conclusion, MRT and ERT are promising approaches in the use of exercise to prevent obesity and consequently Type 2 Diabetes. BMI and body weight appeared to respond significantly to MRT, whereas ERT led to a significant decrease in body fat and increase in skeletal muscle area. The investigation provides important novel insight for prevention and treatment. The effects discovered here may depend on the approach to resistance training in this study and the choice of a comparative design. Superior prevention may result from a combination of the two approaches.

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REFERENCES

1. Anderson J. W., Kendall C. W., Jenkins, D. J. (2003) Importance of weight management in type 2 diabetes: review with meta-analysis of clinical studies. JACN 22: 331–339
2. Association W. M. (2008) Declaration of Helsinki: ethical principles for medical research involving human subjects. http://www.wma.net/en/30publications/10policies/b3/17c.pdf
3. Baldi J. C., Snowling N. (2003) Resistance training improves glycaemic control in obese type 2 diabetic men. Int. J. Sports Med. 24: 419–423
4. Bernstein R. K. (2007) Dr. Bernstein's diabetes solution: the complete guide to achieving normal blood sugars (Newly rev. and updated ed.). Boston, Mass. London: Little, Brown
5. Black L. E., Swan P. D., Alvar B. A. (2010) Effects of intensity and volume on insulin sensitivity during acute bouts of resistance training. J. Strength Cond. Res. 24: 1109–1116

6. Boursier V. (2006) Le syndrome metabolique (Metabolic syndrome). (English Abstract Review). Journal des Maladies Vasculaires. 31: 190–201
7. Braith R. W., Stewart K. J. (2006) Resistance exercise training: its role in the prevention of cardiovascular disease. Circulation. 113: 2642–2650
8. Cederholm J., Wibell L. (1991) Impaired glucose tolerance: influence by environmental and hereditary factors. Diabete Metab. 17: 295–299
9. Eberhart M. S., Ogden C., Engelgau M., Cadwell B., Hedley A. A., Saydah S.H. (2004) Prevalence of overweight and obesity among adults with diagnosed diabetes – United States, 1988–1994 and 1999–2002. Morb. Mort. Weekly Rep. 53: 1066–1068
10. Durnin J. V., Womersley J. (1973) Total body fat, calculated from. body density, and its relationship to skinfold thickness in 571 people aged 12–72 years. Proc. Nutr. Soc. 32: 45A
11. Feldstein A. C., Nichols G. A., Smith D. H., Stevens V. J., Bachman K., Rosales A. G. (2008) Weight change in diabetes and glycemic and blood pressure control. Diabetes Care. 31: 1960–1965.
12. Gillies C. L., Abrams K. R., Lambert P. C., Cooper N. J., Sutton A. J., Hsu R. T. (2007) Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: systematic review and meta-analysis. BMJ. 334: 299
13. Gillies C. L., Lambert P. C., Abrams K. R., Sutton A. J., Cooper N. J., Hsu R. T. (2008). Different strategies for screening and prevention of type 2 diabetes in adults: cost effectiveness analysis. BMJ. 336: 1180–1185
14. Gordon B. A., Benson A. C., Bird S. R., Fraser S. F. (2009) Resistance training improves metabolic health in type 2 diabetes: a systematic review. Diabetes Res. Clin. Pract. 83: 157–175
15. Hansen E., Landstad B. J., Torjesen P. A., Gundersen K. T., Svebak S. (2011) Insulin sensitivity after maximal and endurance resistance training. J. Strength Cond. Res. (in press)
16. Houmard J. A., Hortobagyi T., Neufer P. D., Johns R. A., Fraser D. D., Israel R. G. (1993) Training cessation does not alter GLUT-4 protein levels in human skeletal muscle. J. Appl. Physiol. 74: 776–781
17. Manson J. E., Rimm E. B., Stampfer M. J., Colditz G. A., Willett W. C., Krolewski A. S. (1991) Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. Lancet. 338: 774–778
18. Miller W. J., Sherman W. M., Ivy J. L. (1984) Effect of strength training on glucose tolerance and post-glucose insulin response. Med. Sci. Sports Exerc. 16: 539–543

19. Myhr, G. (2002) Fokus på MRl og bruk av kontrastmidler. Oslo: Amersham Health
20. Pi-Sunyer X., Blackburn G., Brancati F. L., Bray G. A., Bright R., Clark J. M. (2007) Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. Diabetes Care. 30: 1374–1383
21. Platou C. G., Midthjell K., Romundstad P. R., Hveem K. (2011) Prevalence and prediction of undiagnosed hyperglycaemia in Norway. The HUNT study. (Unpublished material, Submitted)
22. Rasmussen S. S., Glumer C., Sandbaek A., Lauritzen T., Borch-Johnsen K. (2008) General effect on high-risk persons when general practitioners are trained in intensive treatment of type 2 diabetes. Scand. J. Prim. Health Care. 26: 166–173
23. Rennie K. L., Wells J. C., McCaffrey T. A., Livingstone M. B. (2006) The effect of physical activity on body fatness in children and adolescents. Proc. Nutr. Soc. 65: 393–402
24. Santanasto A. J., Glynn N. W., Newman M. A., Taylor C. A., Brooks M. M., Goodpaster B. H. (2011) Impact of weight loss on physical function with changes in strength, muscle mass, and muscle fat infiltration in overweight to moderately obese older adults: a randomized clinical trial. J. Obes. (epub)
25. Schafer S., Kantartzis K., Machann J., Venter C., Niess A., Schick F. (2007) Lifestyle intervention in individuals with normal versus impaired glucose tolerance. Eur. J. Clin. Invest. 37: 535–543
26. Siegel L. C., Sesso H. D., Bowman T. S., Lee I. M., Manson J. E., Gaziano J. M. (2009) Physical activity, body mass index, and diabetes risk in men: a prospective study. Am. J. Med. 122: 1115–1121
27. Sigal R. J., Kenny G. P., Wasserman D. H., Castaneda-Sceppa C. (2004) Physical activity/exercise and type 2 diabetes. Diabetes Care. 27: 2518–2539
28. Smutok M. A., Reece C., Kokkinos P. F., Farmer C., Dawson P., Shulman R. (1993) Aerobic versus strength training for risk factor intervention in middle-aged men at high risk for coronary heart disease. Metabolism. 42: 177–184
29. Szczypaczewska M., Nazar K., Kaciuba-Uscilko H. (1989) Glucose tolerance and insulin response to glucose load in body builders. Int. J. Sports Med. 10: 34–37
30. Weinstein A. R., Sesso H. D., Lee I. M., Cook N. R., Manson J. E., Buring J. E. (2004) Relationship of physical activity vs. body mass index with type 2 diabetes in women. JAMA. 292: 1188–1194
31. WHO. (1999) Definition, diagnosis and classification of diabetes mellitus and its complications. Report of a WHO consultation. Part 1:

Diagnosis and classification of diabetes mellitus. World Health Organization, Department of Noncommunicable Disease Surveillance, Geneva.
32. WHO. (2000) Obesity: Preventing and managing the global epidemic. Report of a WHO consultation, Geneva. 894: 253
33. Wild S., Roglic G., Green A., Sicree R., King, H. (2004) Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care. 27: 1047–1053
34. Williams G. C., Freedman Z. R., Deci E. L. (1998) Supporting autonomy to motivate patients with diabetes for glucose control. Diabetes Care. 21: 1644–1651
35. Yates T., Khunti K., Bull F., Gorely T., Davies M. J. (2007) The role of physical activity in the management of impaired glucose tolerance: a systematic review. Diabetologia. 50 (6): 1116–1126
36. Zachwieja J. J., Toffolo G., Cobelli C., Bier D. M., Yarasheski K. E. (1996) Resistance exercise and growth hormone administration in older men: effects on insulin sensitivity and secretion during a stable-label intravenous glucose tolerance test. Metabolism. 45: 254–260

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CHANGES IN HIP MUSCLE STRENGTH AFTER PROXIMAL FEMORAL FRACTURE IN ELDERLY WOMEN

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ABSTRACT

Hip muscle weakness is an often-occurring condition after displaced fractures of the proximal femur in older patients. The aim of this study was to compare hip muscle strength and pain in elderly female patients after proximal femoral fracture. Nine female patients (mean±SD of 71.4±3.9 yrs) participated in this study. Knee extensor, hip abductor and adductor muscle strength was evaluated with hand-held dynamometer Lafayette (USA) during the first week of post-operative stay in hospital, and 6 months postfracture with fractured and nonfractured leg. Pain was assessed using a visual analogue scale. A week after the operation knee extensor, hip abductor and adductor muscle isometric muscle strength for the fractured leg was decreased ($p<0.05$) by 50.7%, 55.6% and 38.8%, respectively, compared to the nonfractured limb. At 6-month follow-up, hip muscle strength increased significantly ($p < 0.05$) in both the fractured and non-fractured leg. Hip muscle strength for the fractured leg was significantly lower ($p<0.05$) compared with the nonfractured leg 6 months after surgery. Pain score was significantly ($p<0.05$) higher during the first postoperative week as compared to 6 months follow-up.

It was concluded that voluntary maximal isometric force-generating capacity of knee and hip muscles for the fractured leg was markedly increased 1 week and 6 months postoperatively. Isometric

force-generating capacity for the fractured leg was significantly improved by 6 months follow-up.

Key words: proximal femoral fracture, hip muscle strength, pain, older patient

INTRODUCTION

Fractures of the proximal segment of the femur occurring most commonly in elderly patients are a serious medical and socioeconomic problem. Globally there are already more than 1.3 million hip fractures each year. Residual lifetime risk of proximal femoral fractures (PFF) for women and men from 60 age is 44% and 25% respectively [17]. Six months after fracture, 30% of patients die [18], 50% from survivors need assistance in walking and 90% need assistance to climb stairs after one year [4, 5]. Mobility limitations after hip fracture are very common and impaired by deficits of lower-limb muscular strength [12, 15]. Studies of elderly adults have demonstrated that muscle strength deficit is extremely large after PFF [15, 17]. The measurement of muscle strength is a widely used tehnique in geriatrics [1]. The factors related to the impared muscle function may be trauma, surgical treatment, pain, or disuse of the fractured limb [14]. Hip muscles are important in generating maximal leg extensor power, which correlates closely with mobility in elderly subjects. Structured programmes of high-intensity resistance exercise training can achieve marked improvements in muscle function [3].

The aim of this study was to evaluate hip muscle isometric strength after PFF in elderly women during 1 week and 6 months follow-up.

MATERIAL AND METHODS

Subjects

Nine female patients with PFF (mean±SD age of 71.4±3.9 yrs, height 1.65±0.1 m, body mass 69.0±13.3 kg and body mass index 25.3± 5.2 kg/m^2) participated in this study. The subjects were treated by internal fixation in Tartu University Hospital. The fracture types were 31-A1 (1 case, 11.1%), 31-A2 (2 cases, 22.2%), 31-A3 (1 case, 11.1%), 31-B1 (1 case, 11.1%), 31-B2 (4 cases, 44.4%). The type of repair devices were: dynamic hip screw – 2 cases, proximal femoral nail – 2 cases, proximal femoral nail anti-rotation – 2 cases, 3 screw fixation – 1 case, total hip arthroplasty – 2 cases. 55.6% of the participants had left hip and 44.4% – right hip fracture. Patients were excluded if they met any of the following criteria: (1) Folstein Mini-Mental State Examination score less than 25 points; (2) dementia or any other neurodegenerative pathology; (3) any impairment of visual, somatosensory, hearing or vestibular function; (4) inability to walk before fracture. Participants had 30 min. physiotherapy during the first week of hospital stay. The training program included specific exercises for all hip muscle groups to improve mobility, strength, balance and achieve independence in functioning. All participants signed the informed written consent prior to their inclusion in the study. The study carried the approval of the University of Tartu Ethics Committee.

Experimental design

Isometric strength of leg muscles was measured 1 week and 6 months postfracture with hand-held dynamometer Lafayette (USA), whereas the fractured leg was tested first. During the trials the subjects sat on a chair. For measuring knee extension the tested hip and knee were flexed at 90°. The dynamometer pad was held by the investigator on distal part of the lower limb. For measuring hip abduction and adduction the hip and knee were flexed at 90°. The dynamometer pad was held at the lateral and medial femoral condyle respectively. The participants were asked to perform a maximal voluntary isometric contraction. Three trials were performed and the best trial was used for further analysis. Postoperative pain in the hip was evaluated at rest using a visual analogue scale (VAS) at 1 week and 6 months follow-up. Hip muscle weakness was quantified by comparing maximal voluntary isometric strength outcome between the fractured and nonfractured leg.

Statistical analysis

Data are mean and standard deviations (SD). The changes in muscle strength and pain at 1 week and 6 months follow-up were assessed by one-way ANOVA. A level of $p \leq 0.05$ was selected to indicate statistical significance.

RESULTS

Knee extensor, hip abductor and hip adductor muscle isometric strength for the fractured leg compared to the nonfractured leg was significantly lower in the first postoperative week (Figure 1). Six months after fracture, hip muscle strength increased significantly in the fractured and nonfractured limbs compared to the first post-operative week. Six months after surgery, isometric knee extensor, hip abductor and adductor muscle strength for the fractured leg was significantly lower compared with the nonfractured leg. Pain score decreased significantly ($p \leq 0.05$) 6 months after surgery (Figure 2).

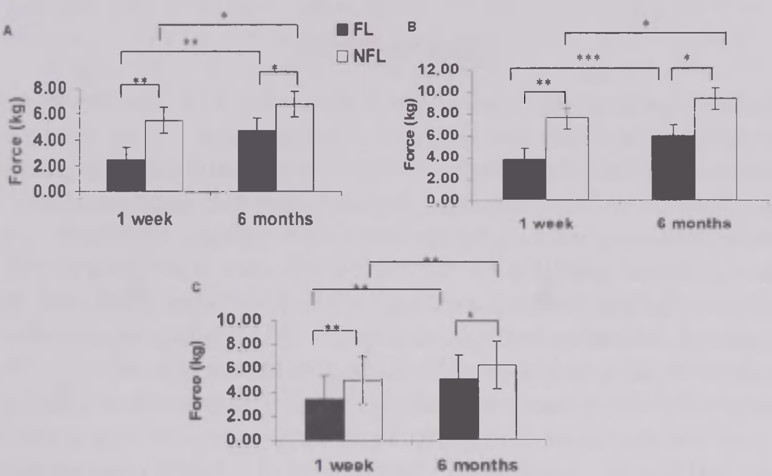

Figure 1. Isometric muscle strength of knee extensors (A), hip abductors (B) and adductors (C) 1 week and 6 months follow-up (mean±SD). FL=fractured leg, NFL=nonfractured leg (mean±SE). $^{*}p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$

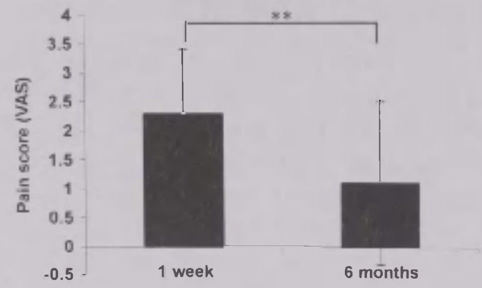

Figure 2. Pain score by VAS scale 1 week and 6 months postfracture (mean±SD). **$p \leq 0.05$.

DISCUSSION

The first conclusion of our study is that after PFF the hip muscle isometric strength for the fractured leg was significantly decreased 1 week and 6 months postoperatively. In our study muscle weakness was observed in knee extensors, hip abductor and adductor muscles: 1 week following the surgery the muscle strength for the fractured leg was decreased ($p \leq 0.05$) by 50.7%, 55.6% and 38.8% respectively, compared to the nonfractured leg. This is in agreement with the results of several previous studies [4, 15], indicating voluntary maximal isometric hip muscle force-generating capacity after hip fractures in elderly women. Portegijs et al. [15] have shown that hip muscle asymmetrical deficit persisted during the first postoperative week and that at 1 week and 13 weeks after PFF surgery, leg extensor power increased in the fractured leg and the nonfractured leg by 100% and 30% respectively, whereas the asymmetrical deficit between the fractured and nonfractured limbs was 28.5%. The reasons of considerable muscle deficit may include a mechanical/anatomical limit, reduced muscle mass (atrophy), postoperative hip pain and edema [4, 13]. In elderly obese patients, diabetes and hypertension can be the reasons of muscle mass loss, which is directly associated with muscle strength loss [1].

The second conclusion is that significant improvement was noted in the strength generating capacity in the fractured leg during 6 months follow-up, but the fractured hip muscle strength deficit compared to the nonfractured leg persisted. Muscle strength improvement can be explained by the various strategies to improve mobility, including gait retraining and exercise programs, which were used during the hospital stay and often after discharge from hospital. The aim of the rehabilitation process was to return elderly patients as quickly as possible to their preoperative functional status [9]. The goal of physiotherapy is to improve mobility, strength and achieve independence [11]. In elderly people Host et al. [8] observed a significant difference in the knee extensor strength measurements between the fractured and nonfractured leg 6 months postfracture. Knee extensors were weaker in the fractured limb than in the nonfractured leg, and this difference reached statistical significance $p<0.5$. Our study demonstrated similar results. It has been shown that six months after the fracture, physical exercises have the potential to improve physical outcomes and induce gains in strength so that the fractured limb is essentially equivalent to the nonfractured limb [20]. Studies of postfracture hip have shown that regular exercise (resistive and/or aerobic) can improve physical performance (gait, strength), mobility, walking speed, and quadriceps strength. In a study of a center-based intervention initiated 6 months after a hip fracture, benefits in muscle strength, walking speed, balance, and physical performance were found [13]. Song et al. [18] have shown that after 6-month postoperative period, subjects in the t'ai chi program had significantly greater knee extensor endurance. Despite the effectiveness of the delivery system and the reported improvements in exercise and physical activity [13], the fractured leg can remain by 20% weaker than the nonfractured leg at 3–36 months after hip fracture [15]. One month after surgery, quadriceps strength decreases to 60% of the preoperative level [19].

The third conclusion is that at 6 months follow-up the knee extensor, hip abductor and adductor isometric muscle strength deficit for the fractured leg was significant ($p\leq 0.05$): 36.8.%, 29.9% and 19.4% respectively. It was less than 14.1%, 25.7% and 19.4%, respectively during the first postoperative week. Muscle data demonstrated a slow recovery of muscles. The results of Rasch et al. [16] study show that 6 months postoperatively, hip muscle deficit was 18% and knee extensors fully recovered after 2 years. Recent studies in elderly people show that between 22% and 75% of hip fracture patients do not recover to their prefracture ambulatory or functional status between 6 and 12 months after the fracture [2]. Quadriceps weakness persists even 6 to 13 years after surgery [19].

The postoperative and earlier recovery period after surgery is characterized by reduction of muscular loading and has been associated with atrophy of the thigh muscle fibres [6]. Loss of function is expected after PFF [17]. Impared hip muscle function may be an important modifiable contributor. Following PFF there is reduction in fast-twich muscle fibre size in the quadriceps. These fibres are important in generating maximal leg extensor power which correlates closely with mobility in frail elderly subjects after PFF [3].

Pain is one of the factors which may affect functional outcomes during the first postoperative week. Our study demonstrates that the pain score was significantly ($p<0.05$) higher during the first week as compared to 6 months follow-up. The few studies of patients with hip fractures have focused on management of perioperative pain symptoms or the relationship between acute postoperative pain and functional outcomes [7]. Portegijs et al. [15] demonstrate that at 1 week after surgical repair of the PFF, 12% of the participants experienced no pain, 40% had occasional or slight pain, 23% had pain on initiation of activity, 14% had pain with activity, 7% had constant yet bearable pain, and 5% had constant unbearable pain. At week 13, 31% of the women reported no pain, 57% had occasional or slight pain, and 12% had pain on initiation of activity.

It has been shown that pain severity with movement during hospitalization for the hip fracture was a significant predictor of functional outcomes 2 months after surgery. I was found that pain during the first 3 postoperative days was associated with longer hospital stays, more postoperative complications, missed or shortened physical therapy sessions, delayed ambulation, and lower locomotion scores at 6 months after fracture repair. These studies suggest that pain in the immediate postoperative period has a significant effect on short- and long-term functional outcomes after hip fracture [7].

In conclusion, voluntary maximal isometric force-generating capacity of knee and hip muscles for the fractured leg was markedly increased 1 week and 6 months postoperatively. Isometric force-generating capacity for the fractured leg was significantly improved at 6 months follow-up.

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REFERENCES

1. Abizanda P., Navarro J. L., García-Tomás M. I., López-Jiménez E., Martínez-Sánchez E., Paterna G. (2012) Validity and usefulness of hand-held dynamometry for measuring muscle strength in community-dwelling older persons. Arch. Gerontol. Geriatr. 54: 21–27
2. Binder E. F., Brown M., Sinacore D. R., Steger-May K., Yarasheski K. E., Schechtman K. B. (2004) Effects of extended outpatient rehabilitation after hip fracture: a randomized controlled trial. JAMA. 292: 837–846
3. Braid V., Barber M., Mitchell S. L., Martin B. J., Granat M., Stott D. J. (2008) Randomised controlled trial of electrical stimulation of the quadriceps after proximal femoral fracture. Aging. Clin. Exp. Res. 20: 62–66
4. Casartelli N. C., Maffiuletti N. A., ltem-Glatthorn J. F., Staehli S., Bizzini M., lmpellizzeri F. M., Leunig M. (2011) Hip muscle weakness in patients with symptomatic femoroacetabular impingement. Osteoarth. Cartil. 19: 816–821
5. Eastwood E. A., Magaziner J., Wang J., Silberzweig S. B., Hannan E. L., Strauss E., Siu A L. (2002) Patients with hip fracture: subgroups and their outcomes. J. Am. Geriatr. Soc. 50: 1240–1249
6. Gapeyeva H., Buht N., Peterson K., Ereline J., Haviko T., Pääsuke M. (2007) Quadriceps femoris muscle voluntary isometric force production and relaxation characteristics before and 6 months after unilateral total knee arthroplasty in women. Knee Surg. Sports. Traumatol. Arthrosc. 15: 202–211
7. Herrick C., Steger-May K., Sinacore D. R., Brown M., Schechtman K. B., Binder E. F. (2004) Persistent pain in frail older adults after hip fracture repair. J. Am. Geriatr. Soc. 52: 2062–2068
8. Host H. H., Sinacore D. R., Bohnert K. L., Steger-May K., Brown M., Binder E. F. (2007) Training-induced strength and functional adaptations after hip fracture. Phys. Ther. 87: 292–303
9. Lieberman D., Lieberman D. (2002) Rehabilitation after proximal femur fracture surgery in the oldest old. Arch. Phys. Med. Rehabil. 83: 1360–1363
10. Marottoli R. A., Berkman L. F., Cooney L. M. Jr. (1992) Decline in physical function following hip fracture. J. Am. Geriatr. Soc. 40: 861–866
11. Mehta S. P., Roy J. S. (2011) Systematic review of home physiotherapy after hip fracture surgery. J. Rehabil. Med. 43: 477–480

12. Nguyen N. D., Ahlborg H. G., Crnter J. R., Eisman J. A., Ngyyen T. V. (2007) Residual lifetime risks of fractures in women and men. J. Bone. Miner. Res. 22: 781–788
13. Orwig D. L., Hochberg M., Yu-Yahiro J., Resnick B., Hawkes W. G., Shardell M., Hebel J. R., Colvin P., Miller R. R., Golden J., Zimmerman S., Magaziner J. (2011) Delivery and outcomes of a yearlong home exercise program after hip fracture: a randomized controlled trial. Arch. Intern. Med. 171: 323–331
14. Portegijs E., Rantanen T., Kallinen M., Heinonen A., Alen M., Kiviranta I., Sipilä S. (2009) Lower-limb pain, disease, and injury burden as determinants of muscle strength deficit after hip fracture. J. Bone. Joint. Surg. Am. 91: 1720–1728
15. Portegijs E., Sipilä S., Rantanen T., Lamb S. E. (2008) Leg extension power deficit and mobility limitation in women recovering from hip fracture. Am. J. Phys. Med. Rehabil. 87: 363–370
16. Rasch A., Dalén N., Berg H. E. (2010) Muscle strength, gait, and balance in 20 patients with hip osteoarthritis followed for 2 years after THA. Acta. Orthop. 81: 183–188
17. Sherrington C., Tiedemann A., Cameron I. (2011) Physical exercise after hip fracture: an evidence overview. Eur. J. Phys. Rehabil. Med. 47: 297–307
18. Song R., Roberts B. L., Lee E. O., Lam P., Bae S. C. (2010) A randomized study of the effects of t'ai chi on muscle strength, bone mineral density, and fear of falling in women with osteoarthritis. J. Altern. Comp. Med. 16: 227–233
19. Stevens-Lapsley J. E., Balter J. E., Kohrt W. M., Eckhoff D. G. (2010) Quadriceps and hamstrings muscle dysfunction after total knee arthroplasty. Clin. Orthop. Relat. Res. 468: 2460–2468
20. Sylliaas H., Brovold T., Wyller T. B., Bergland A. (2011) Progressive strength training in older patients after hip fracture: a randomised controlled trial. Age Ageing 40: 221–227

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POSTURAL CONTROL AND VERTICAL JUMPING PERFORMANCE IN ADOLESCENT AND ADULT MALE BASKETBALL PLAYERS

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ABSTRACT

The purpose of this study was to compare postural control and vertical jumping performance characteristics in adolescent and adult male basketball players. Forty nine male basketball players participated in this study. They were distributed into three groups: (1) young adolescents (YA; with mean age 15.4±0.7 yrs), (2) old adolescents (OA; 17.9±1.2 yrs), and (3) adults (AD; 25.9±3.7 yrs). Static standing balance during bi- and unipedal standing and vertical jumping characteristics were measured on a force platform. AD basketball players had significantly ($p<0.05$) higher vertical jumping height and power development per unit of body mass as compared to YA and OA group; OA group outperformed YA group as well. Static standing stability was better in AD group than YA and OA group. There were no significant differences between YA and OA groups in static standing balance test. Age and sports participation were significantly ($p<0.05$) positively correlated with vertical jumping height and power. Anthropometrical characteristics and sports participation were all significantly ($p<0.05$) negatively correlated with centre of pressure trace length during bi- and unipedal standing. No significant correlation was observed between balance and vertical jumping characteristics. It was concluded that in male basketball players the improvement in vertical jumping performance and static standing balance during bipedal stance are influenced by sports participation and maturation, whereas static standing balance during unipedal stance is not affected by aforementioned factors.

Key words: postural control, vertical jumping performance, young adults, basketball

INTRODUCTION

Popular sports, like basketball have high performance demands on an athlete. On the other hand, the risk of sustaining sports injuries is high. Deficits in postural control and muscle power represent two important intrinsic injury risk factors [3, 8, 16]. Age and sports specific training can have an influential effect on these characteristics [5]. Higher-level basketball player is moderately strong, powerful and has a quick, explosive burst of speed, as well as good endurance to repeat it throughout the game [5, 6, 12]. Good flexibility, stability and balance are also required to help reduce the possible incidence of injury [13]. The literature suggests that there is an association between lack of balance [3, 16], as well as deficits in muscle strength (lower limb power) and lower extremity injuries [8]. Impaired postural control manifests itself, for example, in prolonged latencies of lower extremity muscles during the compensation of unexpected perturbations. Deficits in muscle strength may cause an imbalance in muscular co-contraction of the ankle or knee joint resulting in reduced joint stiffness during high-load dynamic activities and increase the risk of an injury [11, 13, 16].

The ability to control the balance of the body while standing is a complex and integrative processing from a variety of sensory and motor inputs [17] and is fundamental for different types of physical activities. It is a basis for further control and coordination of more complex movements and therefore has an important role in sports activities, such as basketball. Although Hobbs [9] concluded that neither dynamic nor static balance is a factor in basketball playing ability, other studies [14] found that performing high-level movements during practice and competition requires both static and dynamic balance. Scores of postural balance are frequently used to identify players with chronic ankle instability [4]. Balance is often measured by having subjects stand on a computerized force-platform. Centre of pressure (COP) motion is indicative of postural control and is measured from the ground reaction forces from a force platform. COP displacement is generally considered the gold standard measure of balance. The single-limb stance test on a force-platform is a reliable method [1, 2] and is commonly used for evaluation of functional instability and ankle ligament injuries [13, 15, 18]. Cross-sectional studies have found that athletes generally have superior balance ability compared with control subjects [11]. This implies that sport participation improves balance, although it varies between sports. Normally, sports training improves bipedal postural control and decreases the difference between static and dynamic balance. Studies have shown that basketball players have better balance than non-athletes, but worse than soccer players, especially in unipedal balance, because basketball players rarely engage in unilateral stationary balance, whereas soccer players often perform dynamic unilateral movements when kicking the ball [11].

Success in many sports depends heavily upon the athlete's explosive leg power and muscular strength. An athlete must be able to use strength as quickly and forcefully as possible. For the purpose of athletic performance testing for basketball players, the vertical jump test has been shown to be the best predictor of playing time [10]. Variations of vertical jump are the most commonly employed measure for lower body explosive power or speed-strength performance.

The aim of this study was to compare postural control and vertical jumping performance characteristics between adolescent and adult male competitive basketball players.

METHODS

Subjects

A total of 49 male basketball players participated in the present study. The subjects were categorized into the following groups: (1) young adolescents (YA) represented players who competed in Estonian B and C league; (2) old adolescents (OA) represented players who competed in Estonian A league; and (3) adults (AD) represented players who competed in Estonian first league (Table 1). All subjects were confirmed to be healthy and allowed to participate in regular trainings by a medical doctor. Besides, each subject was screened by a questionnaire to exclude those with recent (up to 6 months) ankle sprains or other lower extremity or back complaints.

Table 1. Age and anthropometric characteristics of the subjects (mean±SD).

Groups	n	Age (yrs)	Height (cm)	Body mass (kg)	BMI (kg·m²)	Sports participation (yrs)
Young Adolescents	26	15.4 ± 0.7	186.2 ± 8.1	73.9 ± 9.7	21.3 ± 2.2	6.4 ± 2.0
Old Adolescents	16	17.9 ± 1.2	188.3 ± 4.9	80.8 ± 10.4	22.7 ± 2.2	8.9 ± 1.9
Adults	7	25.7 ± 3.7	200.7 ± 7.0	97.4 ± 11.3	24.1 ± 1.9	15.3 ± 1.9

BMI – body mass index

Experimental protocol

The subjects were scheduled for the testing one day after an easy practice or a recovery day. The purpose of the study and procedures were explained to the subjects and all questions were answered. Sex, age, sports participation and lower limb dominance (as determined by asking "Which foot would you use for take-off?") were recorded. After a light warm-up and stretching routine (10 min) the subjects were measured for body height and weight. The bi- and unipedal static balance testing was performed during standing barefoot on the force platform for 30 s. The subjects were familiarized with the positions before testing.

The vertical jumping tests included 3 sets of squat jumps, countermovement jumps and drop jumps. The best results were used for data analysis. The drop jump box was set at 0.40 m for optimal drop height. To increase the validity of using vertical jump as a specific measure of lower body power, all vertical jump tests were performed without using the arms (keeping the hands on hips), excluding the contribution of upper limbs to vertical jump movement.

Statistical analysis

Standard statistical methods were used for the calculation of means, standard error of the means (±SE) and standard deviation (±SD). A Student unpaired t-test was used to measure differences between groups. Pearson's product-moment correlation was determined between anthropometrical, postural control and vertical jumping characteristics. Statistical significance was accepted at $p<0.05$.

RESULTS

In all three groups there were significant differences ($p<0.05$) in age, body mass and sports participation in years (Table 1). AD group was significantly different ($p<0.05$) from YA and OA group in height. YA group was significantly different ($p<0.05$) from OA and AD group in BMI.

AD group had significantly higher vertical jumping height (Figure 1) and power per unit of body mass (Figure 2) as compared to YA and OA group; OA group outperformed YA group as well (Figures 1 and 2). In balance tests AD group had significantly lower COP trace length in bipedal stance than YA group and OA (Figure 3). There were no significant differences ($p>0.05$) between YA and OA group in balance tests (Figures 3 and 4).

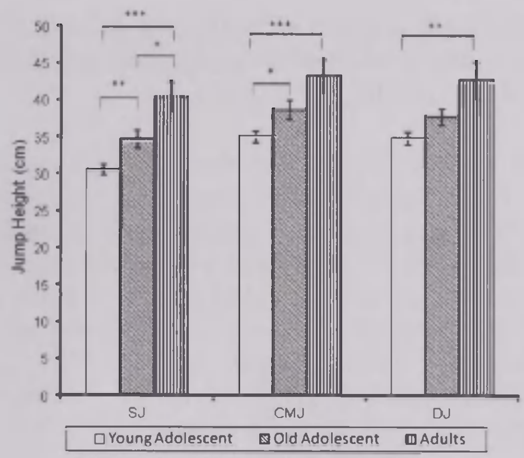

Figure 1. Vertical jumping height in squat jump (SJ), counter movement jump (CMJ) and drop jump (DJ) in male basketball players (mean±SE). * $p<0.05$; ** $p<0.01$; *** $p<0.001$.

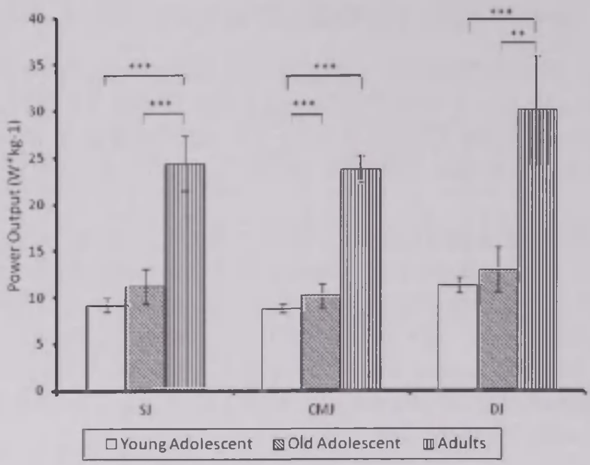

Figure 2. Power output per unit of body mass in squat jump (SJ), counter movement jump (CMJ) and drop jump (DJ) in male basketball players (mean±SE). ** p<0.01; *** p<0.001

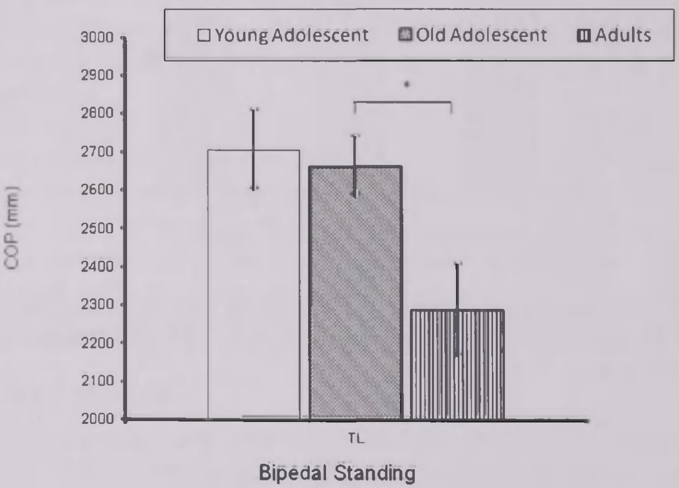

Figure 3. Center of pressure (COP) trace length (TL) during bipedal stance during 30 s standing test (mean±SE). * p<0.05.

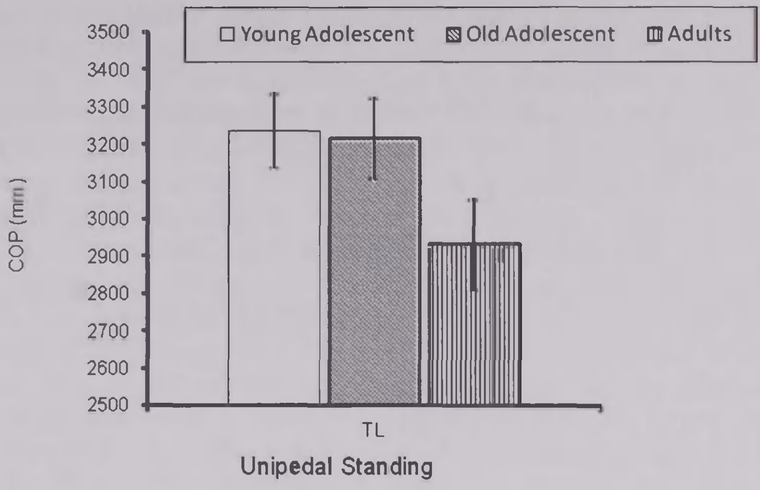

Figure 4. Center of pressure (COP) trace length (TL) during unipedal stance during 30 s standing test (mean±SE).

Age and sports participation had medium to high correlations with vertical jumping performance characteristics ($r=0.48$ to 0.81, $p<0.05$) in different measured groups. Body mass and BMI were negatively correlated with vertical jumping height in all groups, having significant correlation in OA group ($r=0.58$ to 0.59, $p<0.05$). Age, sports participation and anthropometrical characteristics were all negatively correlated with bi- and unipedal COP trace length, but only anthropometrical characteristics had significant correlation ($r=-0.46$ to -0.80, $p<0.05$). No significant correlation was observed between balance and vertical jumping characteristics.

DISCUSSION

This study compared postural control and vertical jumping performance in three groups of male basketball players. Rates of growth and maturation can vary widely within a group of people of same chronological age. The difference of maturation in males in young and teenage groups and difference of anthropometrical characteristics of different playing positions in adolescent group made the groups less homogenous. Besides, basketball players have numerous smaller or bigger injuries throughout their athletic career, which they often do not mention. Thus, the interpretation of results, especially in balance testing, is complicated.

Age, height, body mass, BMI and sports participation correlated with vertical jumping and balance characteristics. Body mass and BMI had positive correlations with relative power in young adolescent and old adolescent groups, whereas these characteristics had negative correlations with relative power in adult group. This suggests that it is important to take into consideration body composition – "active and passive" body mass. Body mass and BMI had clearly negative effect on vertical jumping height in all groups. Negative correlation existed between balance and anthropometrical characteristics, as well as age and sports participation (number of years in basketball practice). Maturation and basketball specific practice improved jumping performance and balance, although no significant correlation existed between age, sports participation and balance. This implies that complimentary to basketball practice, a specific balance and coordination training can be beneficial. Static balance testing alone is probably not sufficient to state this as a proven conclusion. For future research, dynamic balance testing and body composition should be taken into consideration.

Squat jump is a standard test for concentric power production [5]. It is performed from a set squat depth without any countermovement. Countermovement jump is a standard test for combined concentric and stretch-shortening cycle (SSC) performance [5]. Drop jump test is used to assess lower limb reactive (speed-) strength and fast SSC performance [5]. Vertical jumping performance is affected by factors that are trainable and can be manipulated by the athlete (muscular power, coordination of muscles, body weight and composition) and features that cannot be influenced by the athlete (genetic make-up, muscle fibre type, central nervous system efficiency). High efficiency of vertical jump movement allows an athlete to generate the most amount of power with the least amount of effort. Basically the leaner the athletes are (low in body fat) and the less unnecessary muscle mass they have, the higher they are able to jump. Less weight means there is less power needed to jump the same height. Reactive strength is more impacted by body weight, including excess muscle mass. The speed of strength application is often broadly referred to as rate of force development and is an important attribute for vertical jumping performance [7].

In conclusion, the present study indicated that in male basketball players the improvements in vertical jumping performance and static standing balance during bipedal stance are influenced by sports participation and maturation, whereas static standing balance during unipedal stance is not affected by aforementioned factors.

REFERENCES

1. Ageberg E., Zatterstrom R., Moritz U. (1998) Stabilometry and one-leg hop test have high test-retest reliability. Scand. J. Med. Sci. Sports. 8: 198–202
2. Ageberg E., Roberts D., Holmstrom E., Friden T. (2003) Balance in single-limb stance in healthy subjects – reliability of testing procedure and the effect of short-duration sub-maximal cycling. BMC Musculoskel. Disord. 4: 14–30
3. Alexander K. M., LaPier T. L. K. (1998) Differences in static balance and weight distribution between normal subjects and subjects with chronic unilateral low back pain. J. Orthop. Sport Phys. Ther. 28: 378–383
4. Brown, C. N. and Mynark R. (2007). Balance deficits in recreational athletes with chronic ankle instability. J. Athl. Training. 42: 367–373
5. Gamble P. (2010). Strength and conditioning for team sports. Sport-specific physical preparation for high performance. Routledge, London and New York
6. Gillam, G. M. (1985) Identification of anthropometric and physiological characteristics relative to participation in college basketball. Nat. Strength Cond. Assoc. J. 7: 34–36
7. Gruber M., Gruber S. B. H., Wolfgang T., Schubert M., Beck S. C., Gollhofer A. (2007) Differential effects of ballistic versus sensorimotor training on rate of force development and neural activation in humans. J. Strength Cond. Res. 21: 274–282
8. Hakkinen K. et al. (2003) Neuromuscular adaptations during concurrent strength and endurance training versus strength training. Eur. J. Appl. Physiol. 89: 42–52
9. Hobbs M. L. (2008). Dynamic balance and basketball playing ability. Theses and Dissertations-Health and Human Performance. http://ecommons.txstate.edu/hpertad/3
10. Hoffman J. R., Tenenbaum G., Maresh C. M. and Kraemer W. J. (1996) Relationship between athletic performance tests and playing time in elite college basketball players, J. Strength Cond. Res. 10: 67–71

11. Hrysomallis C. (2011). Balance ability and athletic performance. Sports Med. 41: 221–232
12. Latin R. W., Berg K., and Baechle T. (1994) Physical and performance characteristics of NCAA Division I male basketball players. J. Strength Cond. Res. 8: 214–218
13. Leanderson J., Wykman A., Eriksson E. (1993) Ankle sprain and postural sway in basketball players. Knee Surg. Sports Trauma. Arthrosc. 1: 203–205
14. Perrin P., Deviterne D., Hugel F., Perrot C. (2002) Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture. 15: 187–194
15. Rogind H., Lykkegaard J. J., Bliddal H., Danneskiold-Samsoe B. (2003) Postural sway in normal subjects aged 20–70 years. Clin. Physiol. Funct. Imag. 23: 171–176
16. Surve I., Schwellnus M. P., Noakes T., Lombard C. (1994) A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the sport-stirruporthosis. Am. J. Sports Med. 22: 601–606
17. Teasdale N., Stelmach G. E. and Breunig A. (1991) Postural sway characteristics of the elderly under normal and altered visual and support surface conditions. J. Geronthol. 46: 238–244
18. Tropp H., Odenrick P. (1988) Postural control in single-limb stance. J. Orthop. Res. 6: 833–839

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CHANGES IN ELECTROMYOGRAPHIC PARAMETERS DURING CYCLING EXERCISE AT CONSTANT INTENSITY

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ABSTRACT

The aim of this study was to evaluate the changes in surface electromyography (sEMG) parameters during 30-minute cycling exercise (250 W) at constant intensity in laboratory conditions. Ten male cyclists with the mean (±SE) age of 23.8±3.7 years participated. The sEMG power spectrum median frequency (MF) of rectus femoris, vastus lateralis, biceps femoris and erector spinae muscles, heart rate and the subjective rate of fatigue by Borg scale were measured in the beginning, during and at the end of exercise. Maximal voluntary contraction (MVC) force of the knee extensor muscles was assessed before and after the end of exercise. A significant decrease ($p<0.05$) in sEMG power spectrum MF for erector spinae muscle at the end of exercise compared to the initial level was found, whereas the knee extensor and flexor muscles revealed no significant changes in this parameter. The subjective rate of fatigue increased moderately during the cycling exercise ($p < 0.05$). The heart rate was stable during the exercise, remaining predominantly in the aerobic zone. After the exercise, MVC force was significantly ($p<0.05$) decreased compared to the pre-exercise level.

We concluded that based on sEMG power spectrum MF, 30-minute cycling exercise at constant intensity caused a marked fatigue of erector spinae muscle with no significant fatigue-induced changes in knee extensor and flexor muscles. A marked decrease of voluntary force capacity of knee extensor muscles was found after exercise. A moderate subjectively assessed fatigue was established at the end of exercise.

Key words: neuromuscular fatigue, cycling exercise

INTRODUCTION

Muscle fatigue can be defined as the failure to maintain a required or expected power output [3, 9]. This impairment can include peripheral (e.g. neuromuscular propagation, excitation-contraction coupling, myofibrillar activity) and central processes [3, 9, 18]. Numerous studies in this field have focused on measuring neuromuscular fatigue in exercises lasting from 30 minutes to several hours in the last decade [8, 14]. The aetiology of muscle fatigue is very complicated, especially in endurance sports [10, 14]. Many authors describe fatigue, depending on work intensity and the nature of fatigue. There is a firm standpoint that fatigue is the body's defensive reaction that regulates the mobilization of reserves [9, 16, 17, 18]. It is believed that the muscle contraction type (isometric, concentric, eccentric) and the training type (endurance, strength, power) of the neuromuscular system cause neuromuscular functional decrease in performance. However, there is little information how their relationship affects the neuromuscular fatigue development. Surface electromyography (sEMG) analyzes the activity of skeletal muscles by amplitude and frequency parameters. Muscle fatigue has been often evaluated by assessment of median frequency (MF) [1].

Several neuromuscular fatigue studies have dealt with mechanical production of muscular force in sprinting exercises on cycle ergometers [6, 8] and there have also been investigations on training quality relationship with muscle strength and sEMG activity [16]. It has been found that the development of neuromuscular fatigue after prolonged exercise (30 minutes to several hours) is different in cyclists, runners or skiers [14]. This is explained by the adaptation of the neuromuscular system to the muscle contraction that is mainly used in daily sports activities. However, our knowledge of the effect on fatiguing submaximal dynamic exercise to organism functions among athletes of different sports is insufficient. Thus, there is a need for further studies at athletes representing different sports before and after fatiguing exercise.

The purpose of this study was to evaluate the development of fatigue during 30-minute cycling exercise in laboratory conditions at constant intensity. More specifically, we registered the sEMG power spectral MF of rectus femoris, vastus lateralis, biceps femoris and erector spinae muscles, as well as heart rate and the subjective rate of fatigue on Borg scale of the participants during the exercise. Also, fatigue-induced changes in maximal voluntary isometric contraction (MVC) force of the knee extensor muscles were measured.

METHODS

Subjects

Ten male cyclists participated in this study. The mean (±SE) age, body height, body mass and body mass index of the subjects were 23.8±1.2 years, 183.5±2.2 cm, 74.5±2.1 kg and 22.1±0.5 kg/m^2, respectively. The cyclists were the best road cyclists in Estonia. Two cyclists belonged to the Estonian professional cycling team, three cyclists belonged to a French amateur team and five participants were freelancers. The subjects had regularly trained cycling for 11.2±1.3 years prior to the study. The mean training volume among subjects was 16.7±0.8 training hours per week and they had 6.2±0.1 training days per week. Their written informed consent was obtained. The study was carried out at the Laboratory of Kinesiology and Biomechanics of the University of Tartu in June 2010.

Experimental design

The subjects performed 30-minute cycling test using their own racing bicycles, shoes and pedals. Bicycle was fixed to the ergometer Taxc Cosmos. Each subject carried out a standardized warm-up period before each testing session, consisting of 5-minute cycling at constant 100 W intensity. Each subject performed one 30-minute cycling trial at cadence 90 per minute at constant power output (250 W). The heart rate during the test was registered by Polar heart rate tester (Finland). The sEMG electrodes were placed to subject's dominant body side on four muscles: rectus femoris, biceps femoris, vastus lateralis, erector spinae. In order to prevent shifting, wires between the electrodes and the computer were secured to the skin with adhesive tape.

sEMG activity was recorded with surface electrodes T-601. Low impedance between the electrodes was obtained by light abrasion of the skin. Electrodes were coated with electrolytic gel and fixed lengthwise over the middle of the muscular belly. sEMG power spectrum MF of the measured muscles was recorded by electromyograph ME6000 (Kuspio, Finland) for 60 s periods for 3 times: in the beginning (0–1 min), in the middle (14–15 min) and at the end (29–30 min) of exercise.

The subjective rate of fatigue on Borg scale of the participants was registered before the test and for two times during the 30-minute cycling test: at 15 min and at 30 min. Fatigue non-existed at number 6 and fatigue was maximal at number 20 [4]. Every odd number was marked by words. The scale deficiency is its subjectivity and dependence on the subject's self-realization level, therefore it is suitable for experienced athletes.

MVC force of the knee extensor muscles was measured using a custom-made dynamometric chair. During the test, the subjects were instructed to react to the light signal (ignition of the signal lamp, placed 1.5 m from the subject) as quickly and as strongly as possible by extending the right leg against a cuff fixed to a strain gauge system, to maintain the maximal effort as long as the signal was on (2 s) and to relax the muscles after the disappearance of the signal. The subjects were motivated by visual feedback and verbal encouragement. Three maximal attempts were recorded and the best result of MVC force was taken for further analysis. The MVC force was measured before and immediately after 30-minute cycling exercise.

Statistical analysis

Data are expressed by means and standard error of mean (±SE). The significance of the changes for the group of subjects in the beginning, in the middle and at the end of exercise was analyzed by the student t-test. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

sEMG power spectrum MF was significantly decreased ($p<0.05$) at the end of exercise compared to initial level only for erector spinae muscle. For other measured muscles, the changes in MF were not significant ($p>0.05$; Figure 1). The subjective rate of fatigue increased during cycling exercise, whereas this parameter was higher ($p<0.05$) in the middle and at the end of exercise compared to the beginning of the test (Figure 2). The heart rate was stable during the exercise, remaining predominantly in the aerobic zone (Figure 3). MVC force of the knee extensors in cyclists was significantly decreased ($p<0.001$) after the end of 30-minute cycling test at constant intensity compared to the pre-exercise level (Figure 4).

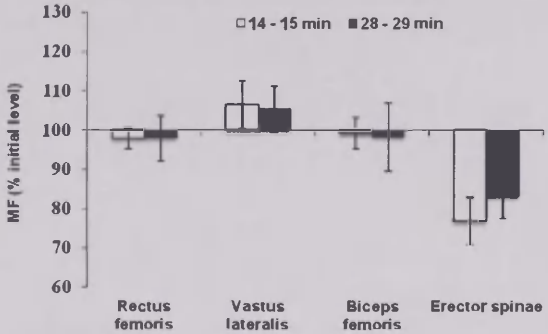

Figure 1. Median frequency (MF) of the electromyography power spectrum recorded from rectus femoris, vastus lateralis, biceps femoris and erector spinae muscles during 30-minute cycling exercise (mean±SE). Values are presented in percent from the initial level in the beginning of the test, taken as 100%. **Significantly ($p<0.01$) different from the initial level.

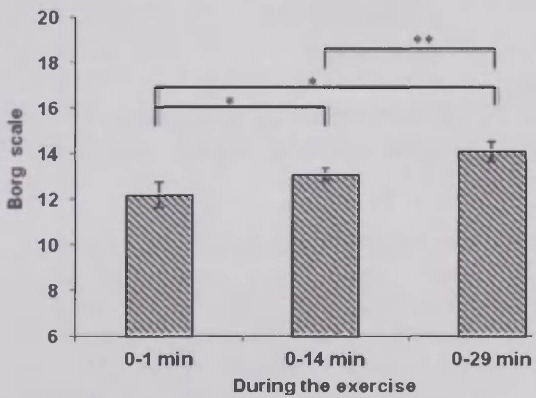

Figure 2. Subjective rate of fatigue evaluated by BORG scale during 30-minute cycling exercise (mean ± SE). *$p<0.05$; **$p<0.01$.

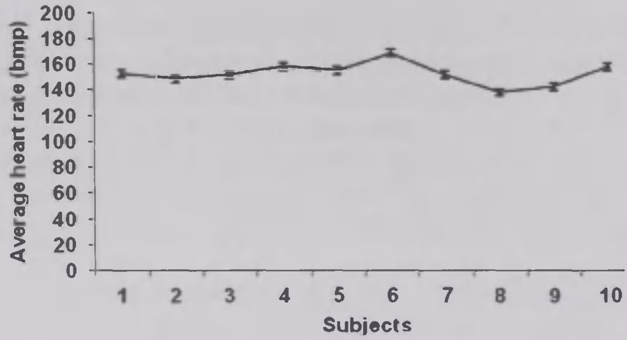

Figure 3. Average heart rate (HRT) of subjects during cycling test (mean±SE).

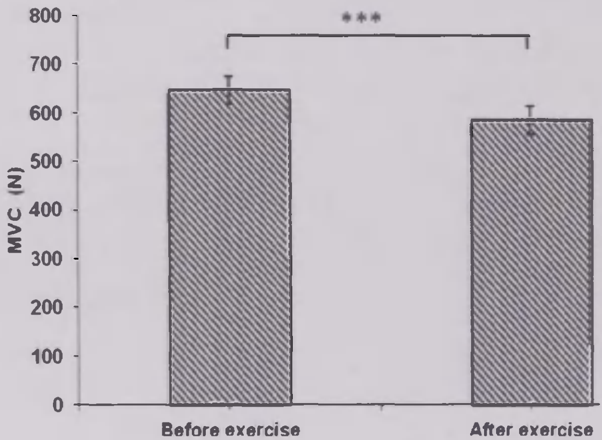

Figure 4. Isometric maximal voluntary contraction (MVC) force of the knee extensor muscles before and after exercise (mean±SE). ***p<0.001.

DISCUSSION

The main results of this study were that 30-minute cycling exercise at constant intensity caused: (a) a significant fatigue of erector spinae muscle during cycling exercise evaluated by decrease of sEMG power spectrum MF and (b) a marked reduction of maximal isometric voluntary force generation capacity of the knee extensor muscles immediately after the end of exercise.

sEMG analysis during the cycling exercise showed that MF of erector spinae muscle was decreased by 16.9% at the end of exercise compared to the beginning of exercise, whereas MF decrease for other measured knee extensor and flexor muscles was smaller (from 2 to 5%). In general, it has been reported that sEMG power spectrum MF decreases as muscle fatigue increases. During sustained fatiguing submaximal contraction, decrease in s EMG power spectrum MF with advancing contraction time has been demonstrated in numerous previous studies [7, 12]. This temporal pattern in the sEMG signal was also observed in the present study. The factors that may contribute to decrease of MF (spectral compression) are decreased muscle fibre conduction velocity [19] and synchronization of the motor units firing [2]. A tendency towards synchronization of motor units reflects a common presynaptic input to motoneuron pool. In the opinion of many authors, motoneuron shifts are caused by a decrease in the membrane conduction velocity occurring during the fatiguing process due to local metabolic changes and ion shifts in the muscles [5].

In this study, the subjective rate of fatigue assessed by Borg scale increased from 12 in the beginning to 14 points at the end of cycling test (16.7%). The cyclists subjectively evaluated this cycling test as an easy exercise. During the test, with increasing load, the rate of subjective fatigue (6.6%) increased to the hard zone. This meant that cyclists felt fatigue, but were able to continue with the given load. At the end of exercise cyclists still evaluated the subjective rate as "hard", being by 14.8% higher compared to the pre-fatigue level. The Rating Scale of Perceived Exertion from 6 to 20 [4] is the most frequently used identification technique of perceived exertion. Pérez-Landaluce et al. [15] found that the Borg scale is a practical measure to prescribe exercise-training intensities in professional, amateur and young cyclists. Fatigue during endurance exercise at constant intensity depends on the conformity of heart rate at given load nature and duration.

In the present study the subjects' heart rate was monitored to assure physiological constancy at the load. There were no significant changes in cyclists', heart rate during the 30-minute cycling exercise at constant intensity. The subjects' average heart rate was between 139–170 bpm. They began the cycling test with the heart rate of 90 bpm and finished the test with the heart rate at 162 bpm. Average heart rate of all subjects during the test was 153±2.7 bpm.

Over the past years, several studies have measured knee extensor muscle strength loss after prolonged exercise. The results of the present study also showed the significant reduction in isometric MVC force of the knee extensor muscles after the cycling exercise. MVC force of knee extensor muscles before the test was 647.7±27.7 N. After cycling exercise, MVC force decreased significantly (9.9%, $p<0.001$) compared to the initial level. MVC loss is consistent with the previous studies conducted with similar cycling intensity and duration [1, 14]. This decrease in maximal isometric voluntary contraction force after exercise may involve processes associated with the central command of contraction [3], as well as peripheral processes of intramuscular electrical and mechanical failure [5]. The failure to maintain the required force can also be related to neural factors (muscle activation) associated with excitation, recruitment and firing rate of motor units. It was noted that corticomotor excitability increases during a sustained submaximal voluntary contraction [11]. This decrease in MVC force generation capacity after fatiguing exercise may similarly involve processes associated with the central command of contraction [2, 13], as well as peripheral processes of intramuscular electrical and mechanical failure [5].

We concluded that based on electromyography power spectrum median frequency, 30-minute cycling exercise at constant intensity caused a marked fatigue of erector spinae muscle with no significant fatigue-induced changes in knee extensor and flexor muscles. Subjectively assessed fatigue was increased at the end of exercise and there was noted a marked decrease in voluntary force generation capacity of the knee extensor muscles after the end of exercise.

REFERENCES

1. Balasubramanian V., Jayaraman S. (2009) Surface EMG based muscle activity analysis for aerobic cyclist. Bodywork Mov. Ther. 13: 34–42
2. Bigland-Ritchie B. (1981) EMG and fatigue of human voluntary and stimulated contractions. Ciba Found. Symp. 82: 130–156
3. Bigland-Ritchie B., Furbush F., Woods J. J. (1986) Fatigue of intermittent submaximal voluntary contractions: central and peripheral factor in different muscles. J. Appl. Physiol. 61: 421–429
4. Borg G. A. V. (1998) Borg's Perceived Exertion and Pain Scales. Champaign IL: Human Kinetics

5. Brody L. R., Pollock M. T., Roy S. H., De Luca C. J., Celli B. (1991) pH-induced effects on median frequency and conduction velocity of myoelectric signal. J. Appl. Physiol. 71: 1878–1885
6. Buttelli O., Seck D., Vandewalle H., Jouanin J. C., Monod H. (1996) Effect of fatigue on maximal velocity and maximal torque during short exhausting cycling. Eur. J. Appl. Physiol. 73: 175–179
7. Clark B. C., Collier S. R., Manini T. M., Ploutz-Snyder L. L. (2005) Sex differences in muscle fatigability and activation patterns of the human quadriceps femoris. Eur. J. Appl. Physiol. 94: 196–206
8. Creer A. R., Ricard M. D., Conlee R. K., Hoyt G. L., Parcell A. C. (2004) Neural, metabolic, and performance adaptations to four weeks of high intensity sprint-interval training in trained cyclists. Int. J. Sports Med. 25: 92–98
9. Edwards, R. H. T, Hill D. K, Jones D. A., Merton P. A. (1977) Fatigue of long duration in human skeletel muscle after exercise. J. Physiol. Lon. 272: 769–778
10. Edwards, R. H. T. (1981) Human muscle function and fatigue. In: Porter R. and Whelan J. (eds.). Human Muscle Fatigue: Physiological Mechanisms. London: Pitman Medical. 1–18
11. Gandevia S. C. (2001) Spinal an supraspinal factors in human muscle fatigue. Physiol. Rev. 81: 1725–1789
12. Masuda K., Masuda T., Sadoyama T., Inaki M., Katsuta S. (1999) Changes in surface EMG parameters during static and dynamic fatiguing contractions. J. Electromyogr. Kinesiol. 9: 39–46
13. Mckay W. B., Tuel S. M, Sherwood A. M. Stokic D. S. Dimitrijevic M. R. (1995) Focal depression of cortical excitability induced by fatiguing muscle contraction: a transcranial magnetic stimulation study. Exp. Brain Res. 105: 276–282
14. Millet G. Y., Lepers R. (2004) Alterations of neuromuscular function after prolonged running, cycling and skiing exercises. Sports Med. 34: 105–116
15. Pérez-Landaluce J., Fernández-García B., Rodriguez-Alonso M., Garcia-Herrero F., García-Zapico P., Patterson A. M., Terrados N. (2002) Physiological differences and rating of perceived exertion (RPE) in professional, amateur and young cyclists. J. Sports Med. Phys. Fitness 42: 389–395
16. Pääsuke M., Ereline J., Gapeyeva H. (1999) Neuromuscular fatigue during repeated exhaustive submaximal static contractions of knee extensor muscles in endurance-trained, power-trained and untrained men. Acta Physiol. Scand. 166: 319–326
17. Rasmussen P., Secher N. H., Petersen N. T. (2007) Understanding central fatigue: where to go? Exp. Physiol. 92: 369–370

18. Sesboüé B., Guincestre J. Y. (2006) Muscular fatigue. Ann. Readapt. Med. Phys. 49: 348–354
19. Stulen F., Deluca C.J. (1981) Frequency parameters of the myoelectric signal as a measure of muscle conduction velocity. IEEE Trans. Biomed. Eng. 28: 515–523

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THE EFFECT OF METHYLPHENIDATE TREATMENT ON EXERCISE PERFORMANCE IN CHILDREN WITH ATTENTION-DEFICIT HYPERACTIVITY DISORDER

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ABSTRACT

The prevalence of attention-deficit hyperactivity disorder (ADHD) in the school-age population is 8–10%, with boys having higher prevalence than girls. Children with ADHD have reduced physical fitness characteristics and exercise capacity compared to healthy children. There are conflicting results regarding the effect of treatment on exercise performance in children with ADHD. We determined fitness characteristic in children with ADHD receiving methylphenidate treatment (17.5±0.6 years; n=16) compared to age-adjusted ADHD children not receiving treatment (17.2±0.7 years; n=16). There were no significant differences in anthropometric measures between the treated and non-treated participants. There were no significant differences in the 60 seconds sit ups number, number of pull-ups, 4X10m shuttle run times and 2000m running times between the treated and non-treated participants. Standing long-jump results were significantly better among the non-treated ADHD participants ($p<0.02$). The results suggest that methylphenidate treatment might be disadvantageous for maximal speed and explosive-type activities in ADHD patient. Further studies are needed to clarify if other sports activities which require attention, accuracy, concentration and organization may benefit from such treatment.

Key words: ADHD, methylphenidate, exercise, children

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a neurobehavioral disorder defined by symptoms of inattention, hyperactivity, and impulsivity. The estimated prevalence rate in the school-age population is 8–10%, with boys having two to three times higher prevalence than girls. Symptoms of ADHD persist into adolescence in 60–80% of the patients, and many continue to have symptoms in adulthood. A leading pathophysiologic hypothesis of ADHD is based on the notion of a catecholamine (CA) dysfunction [6, 7]. This hypothesis suggests that the catecholamine response to environmental stimuli is attenuated in ADHD and is derived primarily from observations that drugs such as methylphenidate (considered to be CA agonists) are effective in treating ADHD symptoms [7].

Previous studies reported that children without ADHD perform significantly better and achieved higher scores in specific skills such as dribbling, kicking, throwing and catching, compared to children with ADHD [3]. Similar results were found when children were asked to performed physical tasks that involve speed and accuracy [2]. The ability of children with ADHD to perform physical tasks that involve high level of coordination was also examined. Hickey et al. [4] have found that children with ADHD had more difficulties in controlling sports oriented objects such as balls compared to non ADHD children. Similarly, ADHD children were found to have more difficulties in hitting the ball in a baseball game than non ADHD children [5]. In another study, ten years observation revealed that 6–8 years old children with ADHD improved significantly less than children without ADHD when coached for basic physical skills such as hops, jumps, side walk and backwards walk [2]. The investigators concluded that physical limitations in children with ADHA sustain throughout life even when practiced continually during maturation. It was speculated that a major reason for the performance inferiority of ADHD children is that they do not put as much effort in training as other children do, and this leads to low self-esteem and lower training impact [5].

The effect of medical treatment on physical performance of children with ADHD is not clear. While it was shown that the use of methylphenidate improves focus, attention, preplanning and ability to complete missions [1, 4, 5], and as a consequence performance in sport-types that require these characteristics, it does not necessarily improves other specific physical skills. Harvey et al. [3] failed to find any improvement in basic motor skills of ADHD children after methylphenidate therapy. Moreover, the use of methylphenidate was associated with a reduction in sport performances that involve speed and power. In addition, the use of methylphenidate was found to increase resting and sub-maximal heart rate, and as a result to impair aerobic performance [2].

The aim of the present study was to examine the effect of treatment with methylphenidate on the physical performance of children with ADHD. We hypothesized that the use of methylphenidate will improve activities that required attention and balance, but impair aerobic and anaerobic capabilities.

METHODS

Participants

Participants included 32 high school boys (16–18 years old) that were diagnosed as ADHD according to accepted criteria. Sixteen ADHD participants were treated with Methylphenidate, while the other 16 ADHD participants were not treated with any medications.

Testing procedure

Each group performed a set of physical test in the following order: 4 X 10 m shuttle run, standing long jump, sit ups, pull ups and 2000 m run.

4 X 10m Shuttle Run – Agility Test

The agility test involved a 4 X 10m shuttle run. The participant began at the base line and ran at maximal speed to a marked line that was located 10m ahead of him. He then turned and ran back to the baseline, turned again and performed the same back and forth run. This procedure was performed twice and the fastest time of the two trials was recorded. The participant rested for 5 min between the two runs.

Standing long Jump – Legs Power Test
Horizontal jump length was measured by a maximum jump using the counter-movement technique. Participants began in an erect standing position, moved into a semi-squat position and leaned forward, before jumping horizontally as far as possible. Three trials were completed with the participant using a vigorous double-arm swing as he jumped off the ground. The longest jump achieved was recorded. All jumps were performed in a long jump pit filled with soft sand. Jumping length was measured manually using a standard measuring tape.

60sec Sit ups – Abdominal Power Test
The participant laid down on the ground with is legs bended and foot attached to the ground by a fellow assister. The participant had to elevate his upper body to 30° off the ground before getting back to starting position. The participant had to keep his hands behind is head at all times. The participant was asked to perform as many elevations as possible during a period of 60sec.

Pull ups – Arms Strength Test
Pull ups were performed on a hanging bar located over the participant head. The participant had to hold the bar with both hands and straight arms. He then had to pull his body up and reach the bar with his chin. No movement of the body to the sides or back and forth was allowed while elevating the body up and down. The participant had to repeat and elevate his body as many times as possible with no time limit.

2000m Run – Endurance Test
The endurance test consisted of a 2000m run. The run was performed on a 400m lap track. The participants ran the 2000m as a group while each used his own tactics to produce the best possible result. Split times were reported to the participants upon completion of each lap. Final times for the run were rounded to full second units.

The participants were familiar with all the testing procedures as they routinely performed them in previous years. Both groups, untreated and treated with methylphenidate, performed the tests during the early morning hours when the effect of the medication is most powerful. The order of testing was similar in both groups. Before starting the first test the participants performed a standard warm-up procedure that included 8 min of jogging followed by 10 minutes stretching exercise and two 20m sprint runs. A 20–25 minutes time period separated between tests while participants were rested and prepared for the next performance. All tests were performed in the same general location and in standard and comfortable environmental conditions.

RESULTS

Anthropometric and fitness characteristics of the study participants are summarized in Table 1. There were no significant differences in anthropometric measures between the treated and non-treated ADHD participants. There were no significant differences in the 60sec sit ups number, number of pull ups, 4X10m shuttle run times and the 2000m running times between the treated and non-treated ADHD participants. Standing long-jump results were significantly better among the non-treated ADHD participants ($p<0.02$).

Table 1. Anthropometric and fitness characteristics of the study participants.

	Non-treated ADHD (n=16)	Treated ADHD (n=16)	P value
Age (years)	17.5±0.6	17.2±0.7	0.15
Height (cm)	177.9±4.2	176.8±2.2	0.47
Weight (kg)	69.5±4.1	70.9±5.9	0.40
Abdomen (#/min)	71.6±10.2	70.6±19.8	0.86
Pull-ups (#)	9.6±5.6	10.1±7.2	0.85
Long-jump (m)	2.25±0.22	2.06±0.24	0.02
4X10m (sec)	9.98±0.56	10.35±0.82	0.15
2000m (min)	10.67±1.60	10.79±2.18	0.86

DISCUSSION

There is a general agreement in the scientific literature that children with ADHD have reduced physical fitness characteristics and exercise capacity compared to healthy children. Decreased performance of ADHD children was found mainly in movement skills (e.g. running, jumping, skipping, hopping), sports-object oriented activities (e.g. dribbling, kicking, throwing, catching) and activities that mandate precision and accuracy [2, 3, 4, 5]. It was suggested that one of the mechanisms responsible for the reduced performance is the inability of children with ADHD to sustain the training process.

The concept that treatment of children with ADHD will improve exercise performance is not obvious. On the one hand, improvement in attention and concentration [1, 4, 5] may improve activities that may benefit from improved precision and accuracy (such as fencing, target or arrow shooting and even basketball throwing), or sports activities that need pre-planning strategy or tactics (like playmaker in a basketball game or even long distance runner that needs to pace running speed), and in situations that the athlete needs to ignore its surrounding (such as noisy and hostile crowd). On the other hand, in sports types characterized by explosive activities (jumping sports), aggressiveness (judo, wrestling, taekwondo) or in situations that hypermobility may give competitive advantage (aggressive defense in ball sports), treatment may reduce exercise performance [2, 3]. Thus, studies regarding the effectiveness of treatment for exercise performance in ADHD children have yielded conflicting results. All together, it is suggested that activities which need attention, concentration, precision and organization may benefit from methylphenidate treatment. In contrast, in aerobic activities, or maximal speed and explosive activities, treatment may be disadvantageous. In most cases, the therapeutic effect on exercise performance results from the drug's effect *per se*. However, the detrimental effect of methylphenidate on aerobic activities [2] results from one of its more common side effects, tachycardia, which occurs during resting conditions and during sub-maximal exercise, and therefore, lowers sub-maximal and maximal oxygen consumption.

In the present study, anthropometric measures were similar between the treated and non-treated ADHD children, thus any difference in performance cannot be attributed to the participant's physique or body size difference. In addition, all exercise tests were performed in the morning hours to guarantee the effectiveness of methylphenidate treatment. Consistent with our hypothesis, standing long-jump performance of the non-treated ADHD children was significantly better than treated children. In contrast, there were no statistically significant differences in the abdominal power test, arm strength test, 4X10m agility test and the 2000m endurance test between the treated and non-treated children. It is possible that these tests are not sensitive enough, and that more complex activities are needed, to find difference between treated and non-treated ADHD children. It is also possible that a larger sample size is needed to find exercise performance statistically significant differences between treated and non-treated children.

In conclusion, it is very important to recognize the exercise performance differences between treated and non-treated ADHD children. Understanding of these differences can assist physical education (PE) teachers during PE classes to find the best way to encourage participation, improve performance and optimize socialization of ADHD children. Acknowledgment of physical fitness characteristic of ADHD children, and the treatment-induced performance changes will help PE teachers to find the best training modalities to strengthen weaknesses and improve performance. This is particularly relevant to athletes with ADHD in order to optimize their training programs and even to direct them to participate in sports types that they may better develop and express themselves. Moreover, since the majority of practices and competitions take place in the afternoon and evening hours when the effect of methylphenidate treatment ceases, it is important that treatment will cover the hours of practice and competitions in ADHD athletes in sports-types that mandate attention, concentration accuracy and organization.

REFERENCES

1. Gapin J., Etnier J. (2009) Physical activity and cognitive performance in children with attention deficit hyperactivity disorder – does physical activity participation predict executive function?. J. Sport Exer. Psychol. 31: 11–12
2. Harvey W. J., Reid G. (2003) Attention deficit hyperactivity disorder: A review of research on movement skill performance and physical fitness. Phys. Activity. 20: 1–25
3. Harvey W. J., Reid G., Bloom G. A., Staples, K., Grizenko N., Mbekou V., Stepanian T., Joober R. (2009) Physical activity experiences of boys with and without ADHD. Phys. Activity Quart. 26: 131–150
4. Hickey G., Fricker P. (1999) Attention deficit hyperactivity disorder, CNC stimulants and sport. Sports Med. 27: 11–21
5. Lullo C., Van Puymbroeck M. (2006) Sport for children with ADHD. Parks Recreation. 41: 20–23
6. Pliszka S. R., McCracken J. T., Maas J. W. (1996) Catecholamines in attention-deficit hyperactivity disorder: current perspectives. J. Am. Acad. Child. Adolesc. Psychiatry. 35: 264–272

7. Zametkin A. J., Rapoport J. L. (1987) Neurobiology of attention deficit disorder with hyperactivity: where have we come in 50 years? J. Am. Acad. Child. Adolesc. Psychiatry. 26: 676–686

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TECHNICAL MODIFICATION OF THE METAMAX II PORTABLE METABOLIC ANALYSER FOR OPERATION WITH A BREATHING APPARATUS

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ABSTRACT

The O_2 uptake of firefighters working in hot and polluted environment is not known. The portable Metamax II might measure the O_2 uptake of firefighters using a breathing apparatus. However, the Metamax requires an inspiration signal between two expirations to work properly. When a firefighter inspires from bottles with pressurised air, the inspired air cannot readily be passed through a metabolic analyser. Expired air is on the other hand released to the surroundings and may be sampled for further analyses. In addition, the Metamax II does not tolerate heat, and gases at the scene of fire may damage its delicate sensors. We have modified the Metamax II, producing an artificial inspiration signal after every expiration. We have also protected the instrument from heat at the scene of fire. Expired air was sampled from exercising subjects using a breathing apparatus. The Metamax II instrument was run in the normal and modified modes while the instrument's reported O_2 uptake was recorded. Control experiments showed that without an inspiration signal, the instrument did not work reliably. In a typical experiment the reported O_2 uptake was only 50% of the true value. In further experiments an artificial inspiration signal was sent to the main unit after every expiration. Then the instrument worked properly although only expired air passed through the Metamax' breathing valve. With proper modifications of the Metamax II, the instrument worked well even if only expired air passed through the breathing valve. The valve may thus be mounted on the outlet of a firefighter's breathing mask. The instrument can readily be protected from heat at the scene of fire and thus be used to measure the O_2 uptake of smoke divers during realistic exercises in hot and polluted environments.

Key words: Metamax II; modification; metabolic analyzer; oxygen consumption, oxygen uptake; fire-fighting; smoke diving.

INTRODUCTION

Physically demanding fire-fighting is often carried out in hot and polluted environments. For scientific examination of the physical demand, direct measurements of the O_2 uptake are needed. This can in principle be done using modern, electronic equipment. However, such instruments do not tolerate high temperatures, and polluted air may affect the delicate sensors, which make direct measurements difficult [5, 10]. Since the instrument needs protection beyond that of the standard housing when used in such extreme conditions, no studies have to our knowledge measured the O_2 uptake of firefighters using a breathing apparatus, working in hot and polluted environments.

A fire-fighter is usually dressed up as a smoke diver, using protective clothing including a face mask with dedicated valves, inspiring from bottles with pressurized air, while expired air is released to the surroundings through the mask's outlet valve. Thus, inspired air is not readily available for analyses, while the expired air may be sampled for further analyses. We have in this study examined the Metamax II metabolic analyzer for use with a breathing apparatus and a face mask in hot conditions. While the Metamax calculates the O_2 uptake from measurements on expired air only, the instrument may need an inspiration signal between two expirations to work properly according to information from the manufacturer. Since only expired air is available for analyses on smoke divers, we had to modify the instrument, producing an artificial inspiration signal after every expiration. We have in addition improved the thermal and mechanical protection since the standard housing may not protect against the high temperatures and possibly hard physical contact met when working in the heat or with heavy tools during fire-fighting. We here describe these modifications and show that the instrument worked properly.

METHODS

The Metamax II instrument

Basic design and principles of operation

The Metamax II instrument (Cortex Biophysic, Leipzig, Germany; serial number of our instrument: MII 63 229901) consists of a main unit housing sensors analyzing fractions of O_2 and CO_2 in sampled air, a built-in barometer, a display and control buttons, electronics and software for analysing the raw data, and connections for other parts (the Triple V breathing valve, power supply) as well as for communication (telemetry, PC through a common RS 232 port). Respired air is measured by the Triple V mounted on a mouth piece or a face mask. The Triple V is a turbine-type flow sensor. More specifically, when air flows through the turbine with twisted stators, air drives a lightweight rotor (20mg) that rotates in close proportion to the amount of air passed through. The rotor's movements are recorded by two sets of infrared photodetectors organized so that both the volume and direction of the flow are determined, and the signals are fed to the main unit. In addition a small amount of expired air is sampled from the turbine housing during every expiration and sucked to the main unit for analyses of O_2 and CO_2 through a dedicated line. There is no air sampling during inspirations. During field studies this unit is often carried in a harness serving as a small back-pack. The whole instrument carried including accessories for field experiments weighed 1.9 kg in our study. The instrument has been examined elsewhere and found to work properly during normal use [8, 9].

Technical details of the flow recordings

The cable connecting the Triple V to the main unit contains eight wires, of which only five are being used according directions provided by the manufacturer ("Anschluss Triple-V am Metalyzer und Metamax II"). Wire 3 (called flow 1 by the manufacturer), and wire 4 (called flow 2) are of particular interest here. Wire 1 is ground, and wire 6 provides voltage supply that appeared to be only ≈2.7 V; this was too low to give a reliable power supply to the electronics we used (see below for further details). Wire 8 of ≈3.1 V is according to the manufacturer connected to ground thru a 9.1 kΩ resistor, apparently to detect a proper connection.

The optical sensors have two infrared photodiodes, each with a corresponding photocell. During inspiration the signal from flow

1 leads that of flow 2 by 25% of a full square wave cycle (compatible with 45° displacement around the arc), while during expiration the sequence is reversed. This allows the software to distinguish between expirations and inspirations.

We purchased an extension cable to the Triple V (Extension cable DVT/Triple V for volume transducer 130–01–022). The extension cable was cut in two, and each wire was freed and soldered to a small circuit board. The voltage of each wire and the signals between the Triple V and the main unit were read off on an ordinary oscilloscope (Mixed signal oscilloscope 54645D, Hewlett Packard). These recordings verified that that during inspiration the signal of "flow 1" (wire 3) is ahead of that of "flow 2" (wire 4), and that the sequence is reversed during expiration as described above. When the light beam was cut, a high voltage of ≈4.8 V was recorded, while when light hit the photocell, a low voltage of ≈0.2 V was recorded. This suggests that the instrument uses standard TTL (transistor-transistor logic) electronics using a voltage divisor in the main unit and further that the photocell works as a phototransistor pulling down the voltage to a low level when being illuminated. Moreover, our recordings also showed that during use each wire conducts a square wave signal to the main instrument.

Making a false inspiration signal

A Pic 16F 628/20 microprocessor (Microchip Technology, Chandler, AZ, USA) was mounted on the circuit board. The Pic 16F microprocessor has altogether 18 pins named A0–A7, B0–B7 and in addition the two used for voltage supply and ground connection. The processor was programmed in MBasic Professional (B0024, Basic Micro IDE, Farmington Hills, MI, USA) as outlined below.

Since during normal use voltage is supplied to the two flow wires from the main unit and since this supply was broken when the cut extension cable was used, we provided a 5 V supply through ≈10 kΩ resistors to wires 3 and 4 (flow 1 and 2) on the Triple V-side of the circuit board from the voltage supply described below. The signals on flow 1 and flow 2 from the Triple V were connected to pins A2 and A3 of the processor. Pins B1 and B2, respectively, were connected to the corresponding wires on the Metamax side of the board. During expiration the signals on A2 and A3 were read continuously, and the signal of pins B1 and B2 were programmed to match those of A2 and A3, respectively. Thus, during expiration the microprocessor let the signal pass thru. Separate examinations showed that the microprocessor reproduced the square-wave signals even during maximal expirations. If no change on pin A3 was recorded during a period of 0.3 s, an end-of-expiration-flag was set, and the microprocessor then generated a simulated inspiration signal with the following pattern: B1 (flow 1) was set high, and after a pause of 3 ms B2 (flow 2) was set high. After a 4 ms pause B1 was set low, and after a new pause of 3 ms B2 was set low. After 4 ms B1 was again set high. This sequence was repeated 25 times, taking altogether 0.37 s (including some initial commands).

The program included controls of a valid expiration and of whether an inspiration had been generated recently. The circuit board and wiring also included two standard LED connected to pins B3 and B4 of the processor thru resistors of $\approx 300\ \Omega$. These diodes were lit during expiration (green, B3) and when the inspiration signal was generated (red, B4). That allowed us to follow the operation of the program both during development and use.

The Pic microprocessor was supplied by power by a standard commercial 9 V block battery (called 6AM6, 6LR61, or 6LF22 by different manufacturers and classifications) through a 7805 (TO92) 5 V regulator. A battery lasted at least 3 d during continuous use before the voltage dropped to 5 V and the battery had to be replaced. The circuit board is outlined in Figure 1.

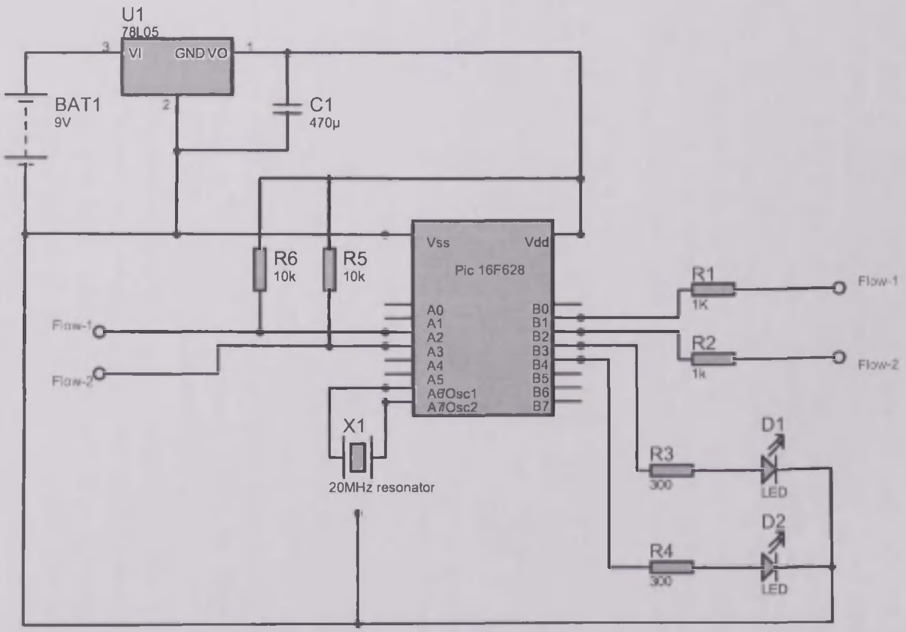

Figure 1. Outline of the circuit board. Upper left, power supply (Bat1) and the voltage regulator (U1). Left, input from the Triple V (Flow 1 and Flow 2). Central, the Pic 16F 628 microprocessor with inputs (A_is) to the left and outputs (B_is) to the right, driven by a 20 MHz resonator (X1). Right, output to the main unit of the Metamax II (Flow 1 and Flow 2). Lower right, output to two photodiodes (D1 and D2). The R*i*-s and C1 are resistors and a capacitor, respectively.

A more robust expiration signal

During the development we learned that one single pulse of the type "flow 2-flow 1" (an expiration-sequence) from the Triple V to the Metamax' main unit was enough to start the pump for sampling of gas to the main unit and thus to record an "expiration" in the Metamax built-in software. Since such pulses occasionally appeared (passive rotation of the rotor, for example because the subject moved the head, or even by a heart beat at rest), we realized that the system was hypersensitive. To reduce that problem we rewrote the program, requiring four such "flow 2-flow 1"-sequences before an expiration signal was let thru. Since this restriction removed four (half) rotations of the turbine fan and thus reduced the instrument's recorded expired volume correspondingly, four extra pulses were added to the pulse sequence to the main unit once expiration had started.

Connecting the Triple V to the Interspiro face mask

The outlet of the Interspiro face mask is covered by a hollow, open cylinder ≈35 mm high and with an outer diameter of ≈78 mm that houses the outlet's valve system. This cylinder thus serves as a cap (here called cap A). The wall at the open end of the cylinder has threads that allow the housing with the valves to be screwed onto the face mask. There is a slit ≈5.6 mm wide around the cylinder wall that allows air to be released, and this outlet is protected by a removable ring ≈3 mm thick and ≈14 mm wide. To sample expired air the protective ring was removed, and a hollow, open cylindrical cap (called cap B) being 41 mm high and with an outer diameter of 90 mm, was mounted around cap A. Gaps between the two caps were closed by commercial silicon glue. Cylinder B had a hole with a diameter of ≈30 mm in the side wall. A pipe 24 mm long was mounted in that hole to serve as a spout. At its open end this spout had an inner diameter of ≈31.3 mm, narrowing in by 3° to match the conically shaped spout on the inlet of the Triple V, thus allowing a tight fit. This modification of the outlet of the Interspiro face mask allowed us to sample and analyse expired air by the Metamax (Figure 2). All parts described above were made of PVC plastic.

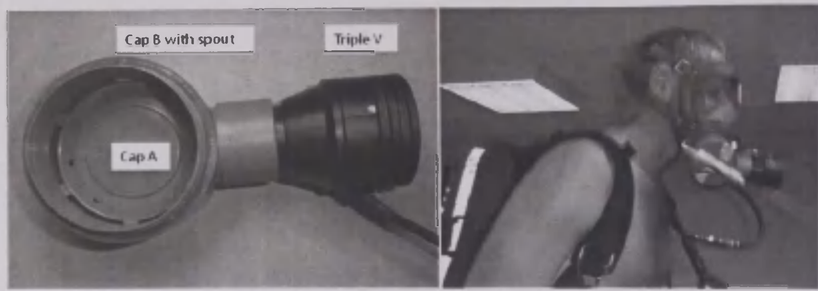

Figure 2. Photos of connections between the Interspiro face mask and the Metamax II. Left, inside of cap A of the outlet of the Interspiro face mask. Holes in the side wall allow air to escape. Cap B with spout around cap A collects released air, leading air through the spout to the Triple V of the Metamax. Right, a subject walking on the treadmill while testing the equipment. The subject is carrying bottles with pressurized air in a harness on his back. Air is led from the bottles to the Interspiro face mask thru a high-pressure hose. The connections shown in detail on the left are mounted on the outlet of the face mask. The white column on cap B contains drierite ($CaSO_4$) that absorbs water vapour from air led to the main unit of the Metamax II for analyses of fractions of O_2 and CO_2.

Heat protection of the Metamax

To protect the equipments against heat and mechanical impacts, the main unit was placed in a box of five-layered plywood filled with an isolating material (Mineral fiber, Protecta, Tønsberg, Norway). The lines connecting the main unit and the Triple V sensor were likewise isolated by a wool stocking tube covered by the same cotton as being used in the firefighters' protective clothings and using fiber tape as outer cover. Measurements showed that even after 8 min in a heat chamber ($T \geq 140$ °C), the temperature in the box never exceeded 25 °C, and the temperature inside the stocking tube was $\leq$40 °C. The box of plywood with additional insulation and straps weighed 3.7 kg. Thus, the box with insulation and the Metamax II with accessories weighed altogether 5.6 kg.

Experiments

Two informed volunteers (staff members) who knew their rights, served as subjects. In one study the subject ran on the treadmill at constant speed and inclination while the O_2 uptake was alternately measured by the Metamax II in the normal mode or when connecting the Triple V to the outlet of a three-way breathing valve. In the latter case only expired air passed through the turbine.

In further experiments the subject cycled twice on separate days on a Krogh-type cycle ergometer [6] at constant power that was increased stepwise at 5 min intervals. Respiratory parameters including the O_2 uptake were measured by the Metamax II. One day the instrument was run in the normal mode. The other day the subjects wore an Interspiro face mask, inspiring from bottles with high-pressurized air. After each expiration the microprocessor generated an artificial inspiration signal that was fed to the main unit of the Metamax II (see above for further details).

RESULTS

The subject ran on the treadmill at constant speed while the O_2 uptake was measured by the Metamax II. When the instrument was run in the normal mode, the reported O_2 uptake varied by 2% between 10 s intervals once a steady state level was reached (open symbols in Figure 3). When only expired air passed thru the Triple V breathing valve, the reported O_2 uptake fell by around 50%, and the reported value varied considerably (filled symbols in Figure. 3).

In further experiments the conditions mimicked that of smoke diving. When the subject inspired from a breathing apparatus, an artificial inspiration signal was generated after every expiration as explained in further detail in the method section. The reported O_2 uptake did not differ systematically from that when the Metamax II instrument was used the normal way (Figure 4). The mean absolute deviation was 24±10 μmol/s (1%). The lung ventilation that in separate control experiments was at least 30% too low when the instrument received no inspiration signal did not differ systematically between the two experimental conditions. The mean absolute deviation was 2.0 ± 0.8 L/min (<5%).

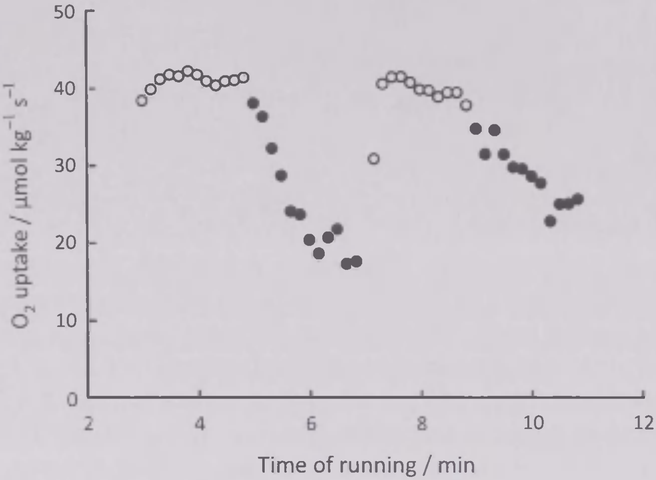

Figure 3. A well-trained middle-aged man ran on the treadmill at 3.33 m/s (12 km/h) at 5% inclination. The O_2 uptake was measured continuously by the Metamax II and reported in 10 s intervals. When the instrument was run in its normal mode where both inspired and expired air passed thru the Triple V breathing valve (○, open symbols), the reported O_2 uptake averaged 40.4 µmol/kg/s with a standard deviation between 10 s intervals of 0.8 µmol/kg/s (2%). When the subject breathed through a three-way valve where the Triple V was connected to the outlet and thus only expired air passed thru the valve (●, filled symbols), the reported O_2 uptake fell considerably.

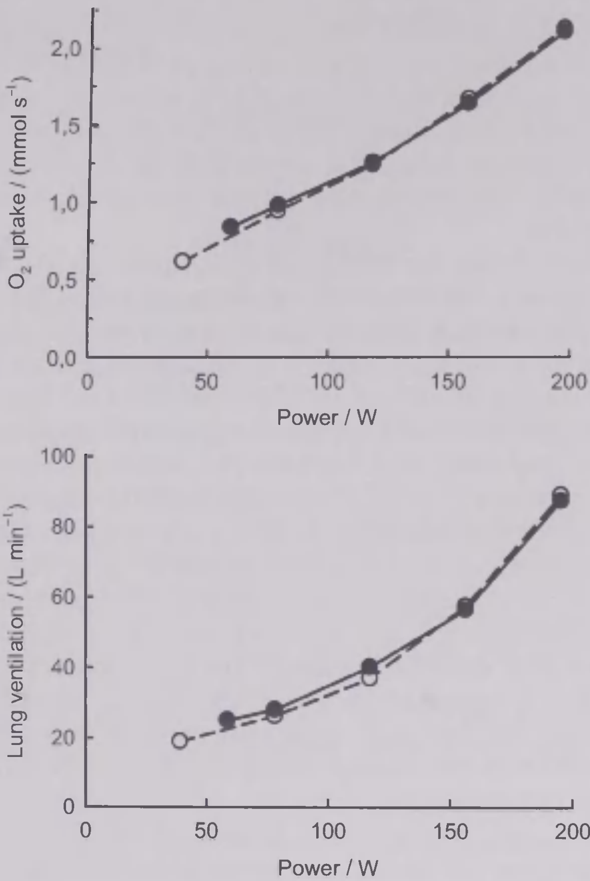

Figure 4. Top panel, O_2 uptake measured by the Metamax II versus power during cycling at stepwise increasing power. Lower panel, lung ventilation versus power during the same exercises. The data are from a subject who cycled for 5 min at each power. During one series the subject inspired from bottles with pressurised air, and the Metamax II was modified to produce an artificial inspiration signal after every expirations when only expired air was passed through the breathing valve (●, filled symbols). In control experiments the subjects cycled while using the Metamax II in its normal mode. This means that both inspired and expired air passed through the breathing valve (○, open symbols).

DISCUSSION

The Metamax II metabolic system requires an inspiration signal between two consecutive expirations to work properly. In our study the reported O_2 uptake fell by around 50% when the instrument did not receive inspiration signals. By producing an artificial inspiration signal between two consecutive expirations, the instrument worked properly when the subject only expired through the instrument's breathing valve.

This study is not the first to sample expired air from subjects breathing from a self-contained breathing apparatus (SCBA), but former studies did not measure the O_2 uptake at hot and polluted conditions. Eves and co-workers [4] mounted a cone of Plexiglas providing an airtight seal around the outlet of the SCBA regulator used, and expired air was led to their metabolic analyser. Several other studies have measured the O_2 uptake on exercising subjects using a breathing apparatus [1–3, 7, 11–13], apparently by simply collecting expired air from the outlet of the breathing apparatus used. In our case we had to produce an artificial inspiration signal to make the Metamax II metabolic system work properly. We have in addition provided heat protection by insulating the instrument, and further protecting it from mechanical impacts. The latter remedies allow us to measure the O_2 uptake while firefighters work in hot and polluted environments. This has to our knowledge not been done earlier, probably because heat may damage metabolic analyzers [5,10]. We also filtered out minor rotations of the fan, rotations that may occur for reasons other than respiration. Such small movements may readily appear both at rest and during exercise, particularly during exercise of moderate intensity with moderate, regular breathing with some interval between the end of expiration and the start of a new inspiration. The filtering introduced may be important since that made the instrument's software more robust against noise. Our software required 0.67 s between the end of one expiration and the start of a new one. That should be problem for firefighters using a breathing apparatus since the apparatus does not allow extremely high ventilations. However, top athletes may breathe as much as 200 L/min with a breathing frequency above 1 Hz. In that case our modification of the Metamax will fail.

We conclude that with proper modifications of the Metamax II, the instrument allows measurements of the O_2 uptake when only expired air passes through the breathing valve. The heat protections introduced may allow measurements of the O_2 uptake during exercise in hot and polluted environments.

This study is part of a larger study approved by the Ethics Committee of Health Region 4 in Norway.

REFERENCES

1. Donovan, K. J., McConnell, A. K. (1999) Fire-fighters' self-contained breathing apparatus (SCBA): The effects of SCBA mass upon exercise duration during treadmill walks in the laboratory. Fire Engineers Journal 59: 23–33.
2. Dreger, R. W., Jones, R. L., Petersen, S. R. (2006) Effects of the self-contained breathing apparatus and fire protective clothing on maximal oxygen uptake. Ergonomics 49: 911–920
3. Eves, N. D., Jones, R. L., Petersen, S. R. (2005) The influence of the self-contained breathing apparatus (SCBA) on ventilatory function and maximal exercise. Can. J. Appl. Physiol. 30: 507–519
4. Eves, N. D., Petersen, S. R., Jones, R. L. (2002) Hyperoxia improves maximal exercise with the self-contained breathing apparatus (SCBA). Ergonomics 45: 829–839
5. Holmer, I., Gavhed, D. (2007) Classification of metabolic and respiratory demands in fire fighting activity with extreme workloads. Appl. Ergon. 38: 45–52
6. Krogh, A. (1913) A bicycle ergometer and respiration apparatus for the experimental study of muscular work. Skand. Arch. Physiol. 30: 375–394
7. Louhevaara, V., Smolander, J., Korhonen, O., Tuomi, T. (1986) Maximal working times with a self-contained breathing apparatus. Ergonomics 29: 77–85
8. Medbø, J. I. (2002) Examination of the time response of the Metamax I and II metabolic analysers at the onset and end of exercise. Acta Kinesiol. Univ. Tartuensis 7: 50–60
9. Medbø, J. I., Mamen, A., Welde, B., von Heimburg, E. D., Stokke, R. (2002) Examination of the Metamax I and II oxygen analysers during exercise studies in the laboratory. Scand. J. Clin. Lab. Invest. 62: 585–598
10. Perroni, F., Tessitore, A., Cortis, C., Lupo, C., D'artibale, E., Cignitti, L., Capranica, L. (2010) Energy cost and energy sources during

a simulated firefighting activity. J. Strength. Cond. Res. 24: 3457–3463

11. Sothmann, M. S., Saupe, K. W., Jasenof, D., Blaney, J., Fuhrman, S. D., Woulfe, T. (1990) Advancing age and the cardiorespiratory stress of fire suppression: Determining a minimum standard for aerobic fitness. Human Performance 3: 217–236
12. Williams-Bell, F. M., Boisseau, G., McGill, J., Kostiuk, A., Hughson, R. L. (2010) Air management and physiological responses during simulated firefighting tasks in a high-rise structure. Appl. Ergon. 41: 251–259
13. Williams-Bell, F. M., Boisseau, G., McGill, J., Kostiuk, A., Hughson, R. L. (2010) Physiological responses and air consumption during simulated firefighting tasks in a subway system. Appl. Physiol Nutr. Metab 35: 671–678

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RUNNING VELOCITY DYNAMICS IN 100 M SPRINT: COMPARATIVE ANALYSIS OF THE WORLD TOP AND ESTONIAN TOP MALE SPRINTERS

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ABSTRACT

Estonian sprint runners have not achieved great success in international title competitions. This study was conducted to analyze their performance in 100m race. The aim of this study was to perform a comparative analysis of 100m sprint horizontal velocity dynamics in Estonian top level and world top-level male sprinters. We analyzed: 1) athletes' relative running velocity during different phases of the distance; 2) the loss of Estonian sprinters to the world best sprinters during different phases of the distance.

The study compared Estonian Athletics Championships (2006) men's 100m sprint final results with Berlin World Athletics Championships (2009) men's 100m final results. In both competitions, interval times were measured for the following sections of the race: 0–30m, 30–60m, 60–80m and 80–100m. We found out that Estonian sprinters' acceleration ability is relatively better than the other physical abilities necessary for achieving good results in 100m. Estonian sprinters loose most to the world best sprinters during the last part of the distance, 80–100m. However, the difference in running velocity of Estonian sprinters compared to the world best runners is approximately the same in all three last sections of the distance (30–60m, 60–80 and 80–100m).

Key words: sprint running, 100m, running velocity, Estonian sprinters

INTRODUCTION

The 100m can rightly be considered the most remarkable event of athletics at major championships. The sheer speed of the 100m allows the winner to claim that he is the fastest runner in the country or in the world. The world best sprinters run 100m faster than 10 seconds, which makes the average velocity over the distance more than 10m per seconds. The world-class athletes make in average 45 steps in a world championship finals [4, 14]. However, during this short time and small number of steps the sprinter experiences four different phases of speed. First, the reaction speed phase in the start; second, the acceleration phase; third, the maximal speed phase; fourth, the speed maintenance phase [8, 13, 14, 15]. Reaction time is a contributor to the overall sprint time, however since it has not been found to be related to sprint performance [9], it was not focused upon in this study.

Different speed abilities have different importance in different sprint distances (100–400m). In 100m sprint running at maximal velocity is often taken as the most important part of the race [1, 2, 5]. According to Ralph Mann the most obvious general performance descriptor in the sprint is horizontal velocity. Ignoring the importance of the start, the athlete that can produce the greatest amount of horizontal velocity will be the most successful [9].

The aim of this study was to perform a comparative analysis of 100m sprint horizontal velocity dynamics in Estonian top level and world top level male sprinters. We analyzed: 1) athletes' relative running velocity during different phases of the distance; 2) the loss of Estonian sprinters to the world best sprinters during different phases of the distance.

MATERIALS AND METHODS

The subjects of the study were 7 Estonian top male sprinters who took part in the final race of 100m in Estonian national championships in Tallinn (21.07.2006). The measurements of running velocity during different phases of 100m distance were done in the following sections: 0–30m, 30–60m, 60–80m and 80–100m. The timing system "Ivar" (accuracy 1/1000 s) designed and built by Ivar Krause was used to measure these split times. The final time of the race was taken from the official competition protocol of results. The timing system of the championships was produced by "Omega" (Switzerland).

Statistical analysis

The relative running velocities (%) of Estonian and world best sprinters in different sections of 100m race (0–30m, 30–60m, 60–80m and 80–100m) were calculated taking the average velocity of the whole distance as 100%. Another calculation was made to find the ratio of Estonian runners' average velocities to world top sprinters average velocities in different sections of the 100m distance. 100% corresponded to the average velocities of different sections of the race in 2009 Berlin World Championship final.

The comparative data about the performance of the world best sprinters was taken from the analysis of 2009 Berlin World Athletics Championships 100m final race [6].

The both finals were run in similar good weather conditions with a tail wind: +0.6 m/s in Estonian Championships and +0.9 m/s in World Championships. Though the difference of 0.3 m/s of wind speed can slightly influence the results in 100m sprint according to J. Mureika calculations [11] we did not considered this small difference relevant enough to make any corrections in our calculations.

RESULTS

The Estonian sprinters showed results in 100m final race from 10.51s up to 11.21s. These results can be considered quite average during this decade. Table 1 presents the split times and the final results of 2006 Estonian Athletics Championships men's 100m final.

Table 1. The split times of men's 100m final in 2006 Estonian Athletics Championships

	Time			
Athlete	**30m**	**60m**	**80m**	**100m**
1.	4.02	6.77	8.61	10.51
2.	4.05	7.00	8.89	10.84
3.	4.03	6.91	8.85	10.93
4.	4.06	7.07	9.00	11.00
5.	4.08	7.17	9.10	11.12
6.	4.06	7.12	9.11	11.15
7.	4.09	7.20	9.17	11.21
Mean ± SD	4.06±0.02	7.03±0.14	8.96±0.18	10.97±0.22

Figure 1 presents the Estonian and the world best male 100m sprinters relative velocities in different sections of the distance. The base for the comparison was the average running velocity over the whole 100m distance. The value of the distance average velocity was taken to be equal to 100%. The values over 100% showed higher velocity and values lower than 100% lower velocity than average in different phases of the distance.

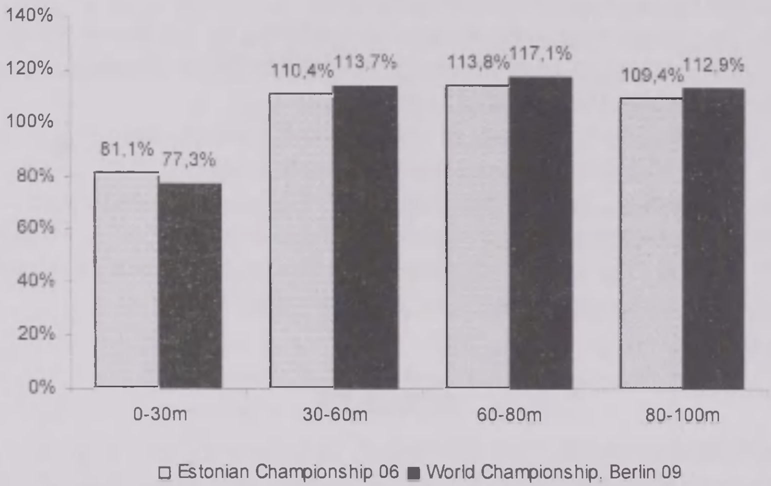

Figure 1. The relative running velocities of Estonian and world best male sprinters in different sections of 100m race: 0–30m, 30–60m, 60–80m and 80–100m. 100% corresponds to the average velocity of the whole distance.

Figure 2 shows how much Estonian sprinters are slower than to the world best sprinters in different phases of 100m sprint. Again, similar to previous analysis the followed distance sections were 0–30m, 30–60m, 60–80m and 80–100m.

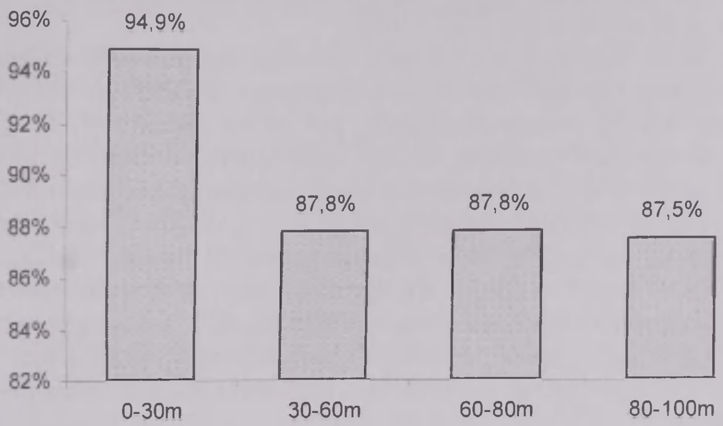

Figure 2. The ratio of Estonian top sprinters' average velocities to the world top sprinters' average velocities in different sections of 100m race. 100% corresponds to the average velocities of different sections of the 100m race in 2009 Berlin World Championships final.

DISCUSSION

This study analyzed horizontal running velocity dynamics of Estonian and world best 100m male sprinters according to the data obtained from 2006 Estonian Championships (abbreviated as EC) and 2009 World Athletics Championships (abbreviated as WC).

Athletes' relative running velocity during different phases of the distance

The relative running velocities of Estonian and the world best athletes is presented in Figure 1. The baseline for the comparison is the average velocity over the 100m distance. The figures show that only in the first section, during acceleration phase, the running velocity is lower than the average velocity of the whole distance. Estonians achieve 81.1% of their average velocity over the first 30m running distance, while the world best sprinters gain 77.3% of their average velocity in this phase of race. It does not mean that the Estonian runners are better accelerators as the mean time in this section was better in the world top sprinters (3.85s vs. 4.06s). But this probably shows that sprinters of lower maximal running velocity level need less time to achieve their maximal velocity.

The next section of the distance, 30–60m, was run with a significantly higher velocity. The world best sprinters achieve their maximal running velocity usually during this part of the distance [7, 10, 12]. Estonian sprinters were able to raise their running velocity by 29.0% in this phase of the race, while the world top sprinters added 36.4% to their running velocity. The explanation of this different capability to add running velocity in this middle section of the distance is probably also related to differences in the levels of maximal running velocity. Estonian sprinters lower maximal velocity enables them to reach their maximal velocity earlier, but does not enable them to raise running velocity as much as the world top sprinters do in the middle section of the race.

Estonian and world top sprinters showed similar running velocity dynamics in the next section of the distance between 60–80m. The velocity in both groups remained rather constant with a small raise in average by 3.4%.

The running velocity decreased similarly in both groups of sprinters in the last section of the distance, between 80 and 100m. Estonian sprinters' running velocity decreased by 4.4% and the velocity of the world top sprinters by 4.1%.

Whilst Estonian sprinters maximal running velocity is considerably lower than world best ones, then to enhance their performance, the key part for Estonian sprinters should be the last parts of the distance. Estonian sprinters might pay more attention to the developing of speed endurance in their training, as there are more opportunities to develop speed endurance than maximal speed. Estonian sprinters should be able to maintain their lower maximal or close to maximal velocity for a longer time. For example in 1987 Rome World Athletics Championships all the male sprinters showed in the 100m final that they were able to achieve maximal running velocity over 11 m/s (Johnson and Lewis even 11.76 m/s). There were also sprinters in the first rounds of the competition who achieved the same maximal velocity (11 m/s), but did not run faster than 10.50 m/s. Good level maximal running velocity does not guarantee a good result in 100m race, but is a good precondition for it. Hence, attention should be paid to the development speed endurance [10].

The loss of Estonian sprinters to the world best runners in running velocity during the different phases of the race

For this analysis the same data from EC 2006 and WC 2009 men's 100m final was used. The results show a clear tendency that Estonian sprinters loose to the world best sprinters less in the first section of the distance (0–30m), only 5.1%. The loss to the world top runners is higher and approximately at the same amount (between 12.2%–12.5%) for the other sections of the distance (30–60m, 60–80 and 80–100m), (Figure 2). Estonian sprinters have relatively better acceleration ability compared to the rest of the physical abilities necessary to run 100m at high level. Estonian sprinters loose to world best sprinters most in the last section of the race (80–100m) where the loss rises to 12.5%. Breizer and Zukov [3] compared world best sprinters with Russian top sprinters and found the same tendency. The Russian sprinters loose most in the last part of the distance between 80 and 100m where athlete should be able to maintain the running velocity close to the maximal.

ACKNOWLEDGEMENTS

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REFERENCES

1. Arakawa K. (1990) Analytical Study on Running Velocity Curve. Research Reports of Kanagawa Institute of Technology (Bulletin of Universities and Institutes) 14: 105–109
2. Bowerman W. J., Freeman W. H. (1991) High-Performance Training for Track and Field. Leisure Press, Champaign, Illinois
3. Breizer V., Zukov J. (1984) An Analyses on Sprint Performances. Legkaya Athletika, No 11, reprinted in Modern Athlete and Coach
4. Brüggeman, G. P., Koszewski D., Müller H. (1997) Biomechanical Research Project Athens 1997. Meyer and Meyer Sport, Oxford, 26
5. Cunha L. (2005) The relation between different phases of sprint run and specific strength parameters of lower limbs. ISBS. Beijing

6. Deutscher Leichtathletic Verband. (2009) Scientific Research Project Biomechanical Analyses of World Championships 2009 Berlin: Final Report, Sprint Men [http://www.iaaf.org/mm/Document/Development/Research/05/64/57/20100415075418_httppostedfile_1-BiomechanicsReportWCBerlin2009_Sprint_Men_19905.pdf]
7. Ferro A., Rivera A., Pagola I., Ferreruela M., Martin À., Rocandio V. (2001) Biomechanical analysis of the 7th World Championships in Athletics Seville 1999. New Study of Athletics. 16: 25–60
8. IAAF. (2009) 100m – For the Expert. http://www.iaaf.org/community/athletics/trackfield/newsid=4666.html
9. Mann R. (2010) The Mechanics of Sprinting and Hurdling. Las Vegas
10. Moravec P., Ruzicka J., Susanka, P., Dostal, E., Kodejs, M., Nosek, M. (1988) The International Athletic Foundation/IAAF Scientific Project Report: Time analysis of the 100 metres events at the II World Championships in Athletics. New Study of Athletics. 3: 61–96
11. Mureika J. (2001) A realistic quasi-physical model of a 100m dash. Can. J. Phys. 79: 697–713
12. Müller H., Hommel H. (1997) Biomechanical research project at VI the world championships in athletics, Athens 1997 – sprints
13. Saunders R. (2004) Five Components of the 100m sprint. Modern Athlete and Coach. 42: 1–3
14. Smith M. (2005) High performance sprinting. The Crowood Press Ltd., Ramsbury
15. Sugiyama K., Murata Y., Watanabe H., Takayuki K., Iwase M. (2000) Factor Analysis of Sprint Phases of the Speed Curve of the 100m Dash. 18th International Symposium on Biomechanics in Sports Conference, Hong Kong, China, June 25 – 30, proceedings

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EVALUATION OF WORK-RELATED NEUROMUSCULAR FATIGUE AND DISCOMFORT IN FEMALE SALES WORKERS

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ABSTRACT

The aim of this study was to compare neuromuscular fatigue and discomfort following workday in groups of sales workers, who were working predominantly in standing or sitting position. Ten female sales workers (aged 21–66 yrs), who worked predominantly in standing position (ST) and 9 female sales workers (aged 20–54 yrs), who worked predominantly in sitting position (SI) participated in this study. Neuromuscular fatigue and discomfort after the workday immediately was subjectively evaluated by 10-point visual analogue scale (VAS) in neck, shoulder, low-back and leg regions. Visual-motor coordination was assessed by Grooved Pegboard test and hand grip strength for both arms was tested by hand dynamometer before and after the workday. The results indicated that after the workday, subjectively evaluated neuromuscular fatigue and discomfort in ST group was higher ($p<0.05$) in posterior calf region compared with SI group. SI group felt subjectively significantly higher ($p<0.05$) neuromuscular fatigue and discomfort in shoulder region after the workday as compared to ST group. Before the workday, the Grooved Pegboard test time was shorter ($p<0.05$) in SI group, whereas hand grip strength for right arm was higher ($p<0.05$) in ST group. No significant work-related changes were found in Grooved Pegboard test time and hand grip strength in the measured groups. It was concluded that following the workday, subjectively evaluated neuromuscular fatigue and discomfort was more pronounced in ST group in posterior calf region and in SI group in shoulder muscles. No significant fatigue-induced changes in visual-motor coordination and in voluntary isometric force-generation capacity of hand muscles were established in female sales workers following the workday.

Key words: neuromuscular fatigue, visual-motor coordination, muscle force, sales workers

INTRODUCTION

Musculoskeletal disorders (MSD) are a major cause of work-related disability [9]. It has been suggested that working long time in standing or sitting position causes MSD [10]. Sales workers, who have to stand or sit throughout the workday, are affected by diseases like varicose veins, poor feet blood supply, swelling, heart and circulation problems. Salespersons working predominantly in sitting position (SI) are in forced position and therefore their neck and back muscles are overloaded. Muscles blood supply and oxygen accessibility causes fatigue and pain in muscles. According to Lehman et al [8], sales workers health problems were associated with the low back (32%), wrist (28%), neck (21%) and shoulder (21%). Long-time standing is often associated with musculoskeletal problems, in including discomfort, fatigue and pain affecting the lower limbs, and low back, often in the whole body. People who have to stand up for a long time can suffer more serious health problems such as lower limb swelling and blood flow restriction [3]. Working in sitting position consumes less muscle force, but this body posture causes low back pain, muscle tension, and muscle pain. People who work in sitting position have to consider that their health can deteriorate when they do not exercise or are not otherwise physically active. Lack of movement can cause hypokinesia. Reduced blood flow to muscles can cause fatigue, therefore employees working in sitting position, who do not do physically hard work, feel highly fatigued at the end of workday. Constant sitting affects mostly the neck and lower back region [2].

The aim of this study was to assess neuromuscular fatigue and discomfort in sales workers working in standing or sitting position before and after the workday. The measurements were carried out at the workplace.

METHODS

Subjects

Ten female sales workers, who were working predominantly in standing position (aged 21–66 yrs) (ST) and nine female sales workers, who were working predominantly in sitting position (aged 20–54 yrs) (SI) participated in this study. The anthropometric parameters of the subjects are presented in Table 1. The ST group worked in clothes shop, selling merchandise over the counter, the SI group worked as cashiers in grocery store.

Table 1. Anthropometric parameters of the subject groups (mean ± SE)

Variable	ST group n=10	SI group n=9
Age (yrs)	36.3±4.3	37.6±4.4
Height (cm)	167.9±2.3	169.3±2.7
Body mass (kg)	62.2±2.9***	78.1±8.6
Body mass index ($kg \cdot m^2$)	22.2±1.3	26.9±2.4
Length of employment (yrs)	6.6±1.4	1.8±0,5
General length of employment (yrs)	16.9±4.3	18.2±4.5
Working time per week (hours)	40.0±0.8	41.1±0.7

ST – sales workers, who were working predominantly in standing position, SI – sales workers, who were working predominantly in sitting position. *** p<0.001. Significantly different compared with sales workers, who were working predominantly in sitting position.

Data collection

The measurements were carried out immediately at the end of the workday. The height and body mass of the subjects were measured with metal anthropometer, and electronic scales, respectively and the body mass index (kg/m^2) of the subjects was calculated. In the course of the research, the subjects completed a questionnaire. Neuromuscular fatigue and discomfort were subjectively evaluated in neck, shoulder, and leg regions by visual analogue scale (VAS; Figure 1) [5, 6]. VAS included numbers from 0 to 10. Perceived exertion was estimated in the following way: 0 – not fatigued, 10 – completely fatigued. To evaluate visual-motor coordination was used the Grooved Pegboard test (Model 32025). The Grooved Pegboard test is a manipulative dexterity test consisting of 25 holes with randomly positioned slots. Pegs with a key along one side must be rotated to match the hole before they can be inserted. The duration of the test was recorded. The test was performed in sitting position by using the dominant hand. Hand grip strength was measured with hand dynamometer (Lafayette Dynamometer Model 78011, USA). The handle of the dynamometer was adapted at 1.5 cm distance. The subject pressed dynamometer in standing position, keeping the hands away from the body. Hand grip strength of both extremities was measured, whereas 3 trials were conducted and the best result was taken for further analyses. The results were presented in Newtons (N).

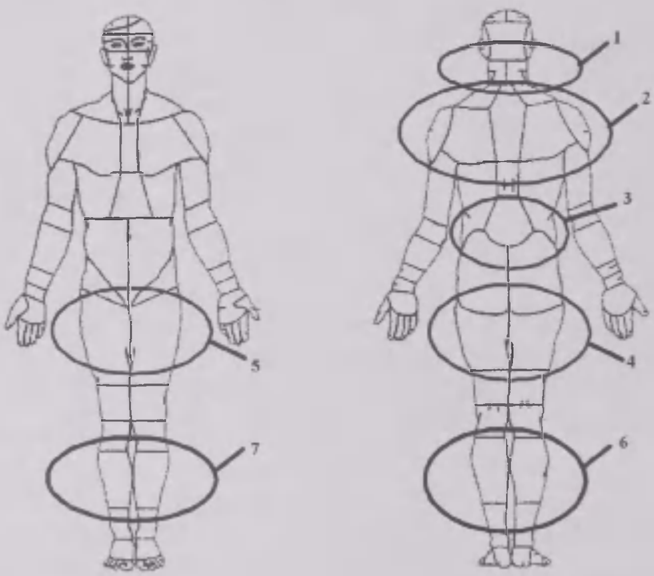

Figure 1. Schematic presentation of subjective evaluation of neuromuscular fatigue and discomfort by visual analogue scale (VAS) from different body regions. 1 – neck, 2 – shoulder, 3 – low-back, 4 – posterior part of thigh, 5– anterior part of thigh, 6 – posterior part of calf, 7 – anterior part of calf.

Statistical analysis

Means and standard errors (±SE) of mean were calculated. The differences of the means of the groups, as well as the significance of the changes for the groups of subjects at the beginning of the workday and after it, were evaluated on the basis of the Mann–Whitney U-test. Comparisons were performed two-tailed and differences were considered significant at $p<0.05$.

RESULTS

According to VAS, SI group felt subjectively significantly higher ($p<0.05$) neuromuscular fatigue and discomfort in shoulder region after the workday as compared to ST group (Figure 2A). After the workday, subjectively evaluated neuromuscular fatigue and discomfort in ST group was higher ($p<0.05$) in posterior calf region compared with ST group (Figure 2B). No significant differences ($p>0.05$) in subjectively evaluated neuromuscular fatigue and discomfort were found in neck, low back, thigh and anterior region of calf in the measured groups of female sales workers. After the workday, the Grooved Pegboard test time in ST group was shorter ($p<0.05$) as compared to the pre-workday level (Figure 3). No significant differences ($p>0.05$) between the measured groups in this parameter were found before and after the workday. Before the workday, hand grip strength for the right arm was higher ($p<0.05$) in ST group compared to SI group (Figure 4), whereas no significant between-group differences were established after the workday. No significant work-related changes following the workday were found in the Grooved Pegboard test time and hand grip strength in the measured groups.

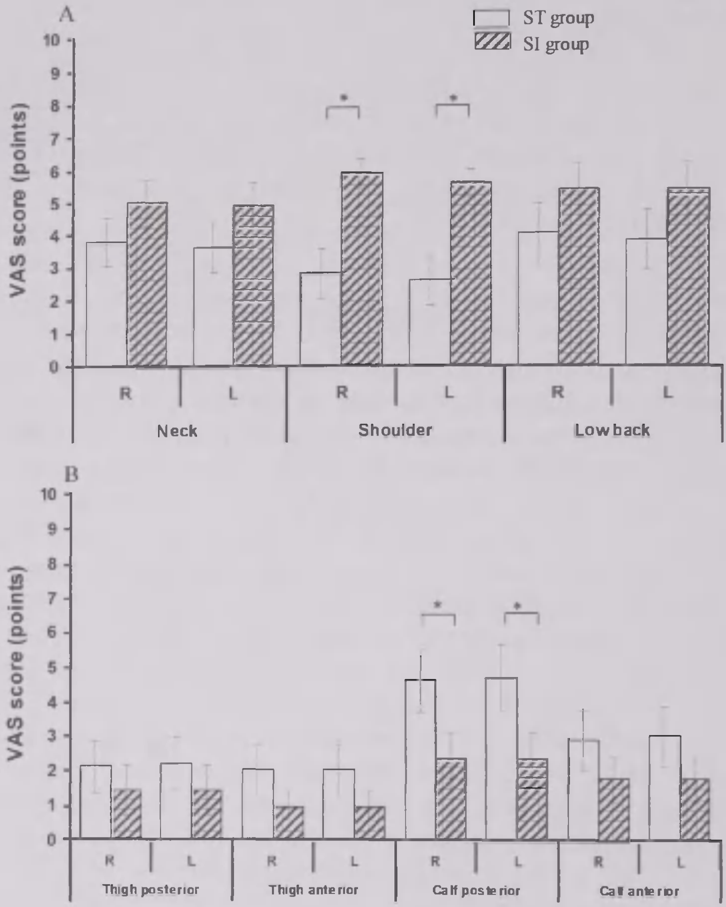

Figure 2. Subjectively evaluated neuromuscular fatigue and discomfort by visual analogue scale (VAS) from different body regions in sales workers, who were working predominantly in standing (ST) or sitting (SI) position (mean±SE). *p<0.05.

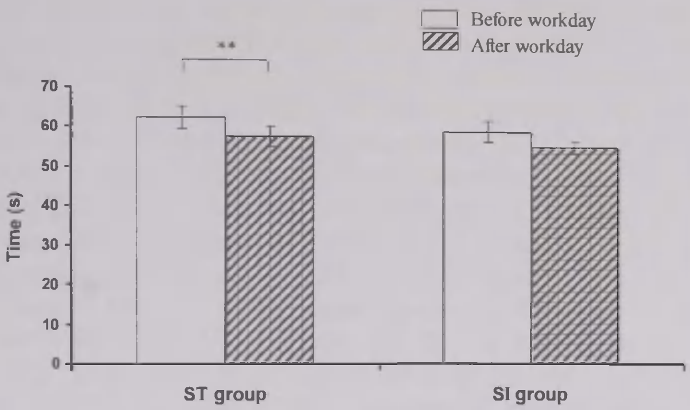

Figure 3. Visual-motor coordination time measured by Grooved Pegboard test in sales workers, who were working predominantly in standing (ST) or sitting (SI) position (mean±SE). **p<0.01.

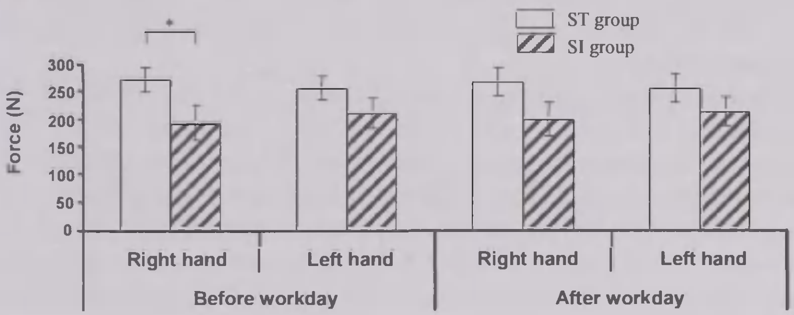

Figure 4. Hand grip strength in sales workers, who were working predominantly in standing (ST) or sitting (SI) position (mean±SE). *p<0.05.

DISCUSSION

Significant discomfort and fatigue of shoulder region (p<0.05) in SI group compared to ST group was observed in this study. In ST group of the subjectively evaluated neuromuscular fatigue and discomfort by VAS in shoulder region was on an average by 47% lower than in SI group. This is agreement with the results of several previous studies [7, 8, 11], indicating a significant reduction of discomfort in the muscles of upper extremities in sales workers, who had to stand throughout the workday. Significant discomfort and fatigue was established in calf posterior muscles in ST group compared to SI group. In the present study subjectively evaluated neuromuscular fatigue and discomfort by VAS in calf region of ST group were by 50% higher than in SI group. In standing position the lower extremities are more loaded than in sitting position, where the most loaded body regions are in shoulders and neck. Physical work requirements and individual factors determine muscle force and length characteristics as a function of time, which in turn determines muscle energy requirements. Muscle energy requirements can lead to fatigue, which can further lead to muscle disorders [8]. This may explain why employees who have to sit throughout the workday (e.g. office workers, cashiers) often experience MSD symptoms in shoulder region and neck [4, 8, 12]. At the end of the workday, no significant differences between ST and SI group were observed in neuromuscular fatigue and discomfort evaluated by VAS in neck, low back, anterior and posterior thigh, and anterior calf in this study. These results are directly related with working position and hypokinesia, which impairs motor ability [1].

In the present study visual-motor coordination time in ST and SI groups was measured. It was found that the visual-motor coordination time was significantly shorter after the workday was as compared to before workday in ST group. Thus, visual-motor coordination was improved following the workday in both groups. At the end of the workday the subjects performed better the visual-motor coordination test, because the test was made for the second time and participants were familiar with its content.

Before the workday, hand grip strength for the right arm was higher on an average by 29% ($p<0.05$) in ST group compared to SI group, whereas no significant between-group differences were established after the workday. The hand grip strength was stabilized in female sales workers, and arms were not fatigued.

Working in standing position increases neuromuscular fatigue and discomfort in calf muscles. It has been suggested that long-term standing on a hard floor causes fatigue and discomfort compared to a softer floor [3]. Regular resting in sitting position reduces fatigue in calf muscles. Relaxing and stretching exercises reduce static tension and discomfort in shoulder region and neck.

Weakness of the present study was a relatively sample size. More research is needed to objectively evaluate fatigue and discomfort, which relates to standing and sitting work position, using myotonometry and electromyography.

It was concluded that following the workday, subjectively evaluated neuromuscular fatigue and discomfort was more pronounced in ST group in posterior calf region and in SI group in shoulder muscles. In ST group visual-motor coordination was improved following the workday. No significant fatigue-induced changes in voluntary isometric force-generation capacity of hand muscles were established in female sales workers following the workday.

REFERENCES

1. Armstrong T. J., Buckle P., Fine, J. (1993) A conceptual model for work-related neck and upper-limb musculosceletal disorders. Scand. J. Work Environ. Health. 19: 73–84
2. Beladev N., Masharawi Y. (2011) The effect of group-exercising on females with non-specific chronic low back pain in a sitting position: a pilot study. J. Back Musculoskelet. Rehabil. 24: 181–188
3. Delleman N. J., Haslegrave C. M., Chaffin D. B. (2004) Working postures and movements: tools for evaluation and engineering. CRC Press
4. Forcier L., Lapointe C., Lortiec M., Buckle P., Kuorinka I., Lemaire J., Beaugrand S. (2008) Supermarket workers: Their work and their health, particularly their self-reported musculoskeletal problems and compensable injuries. Work 30: 493–510
5. Grant S., Aitchison T., Henderson E., Christie J., Zare S., McMurray J., Dargie H. (1999) A comparison of the reproducibility and the sensitivity to change of visual analogue scales, Borg scales, and Likert scales in normal subjects during submaximal exercise. Chest. 116: 1208–1217
6. Hewlett S., Hehir M., Kirwan J. R. (2007) Measuring fatigue in rheumatoid arthritis: a systematic review of scales in use. Arthritis Rheum. 57: 429–439
7. Holte K. A., Westgaard R. H. (2002) Daytime trapezius muscle activity and shoulder-neck pain of service workers with work stress and low biomechanical exposure. Am. J. Ind. Med. 41: 393–405
8. Lehman K. R., Psihogiost J. P., Meulenbroek R. G. J. (2001) Effects of sitting versus standing and scanner type on cashiers. Ergonomics 44: 719–738

9. Okunribido O. (2009) Lower limb MSD. Scoping work to help inform advice and research planning. Health and Safety Laboratory
10. Pensri P., Janwantanakul P., Chaikumarn M. (2010) Biopsychosocial risk factors for musculoskeletal symptoms of the spine in salesspeople. Int. J. Occup. Environ. Health. 16: 303–311
11. Vasseljen O., Holte K. A., Westgaard R.H. (2001) Shoulder and neck complaints in customer relations: individuaal risk factors and perceived exposures at work. Ergonomics 44: 355–372
12. Wahlström J. (2005) Ergonomics, musculoskeletal disorders and computer work. Occup. Med. 55: 168–176

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HOW PHYSIOTHERAPY GRADUATES ESTIMATE PHYSIOTHERAPY CURRICULUM AND IF THE STUDIES HAS AFFECTED THEIR PREPAREDNESS TO WORK AS PROFESSIONAL PHYSIOTHERAPIST

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ABSTRACT

Physiotherapy as an independent curriculum has existed only one decade in Estonia. During this period the curriculum has changed and developed remarkably due to the Bologna Process. Specific feedback about the curriculum from the students who have graduated has not been received. Thus, the aim of the study was to estimate how the physiotherapy students who have graduated from University of Tartu assess the physiotherapy curriculum (theoretical knowledge, practical skills and generic competences). Altogether twenty-nine former students (females=25; males=4) participated in this study. All the participants filled in an anonymous questionnaire. Most of them graduated from the University of Tartu in 2010. 82.2% of the participants had gained Bachelor's and 17.8% Master's Degrees. Approximately 80% of the participants work as physical therapists, mostly in hospitals (37.9%). According to the participants the strengths of the curriculum are: highly qualified professionals are included in the study process; lecturers are also professional physical therapists; strong theoretical basis and versatile practical trainings in school and in clinical environment; modern practical training placements all over Estonia. Weaknesses of the curriculum are as follows: basic subjects are sometimes superficial and there is a lack of specialization (due to lack of time in the three-year study program);

lack of external lecturers; connection between theory and practice is not always sufficient. In spite of this fact that the curriculum offers basic knowledge, practical skills and generic competences (communication skills, team work, sense of duty), the study period is still too short to provide in-depth theoretical knowledge and diverse professional skills. Therefore, there is a need to study more independently during the study process and after graduation (in-service training). It was revealed that some suggestions made by graduates have already been implemented in the course of the recent three years. It means the developments of the curriculum have been adequate and have supported the focus groups` expectations. In conclusion, 180 ECTS are not enough to offer in-depth specialized knowledge and practical skills. According to this result, there is a great need to study further on Master level and/or continue training – lifelong learning.

Key words: physiotherapy curriculum, higher education

INTRODUCTION

Physiotherapy is taught in two different schools is Estonia – University of Tartu and Tartu Health Care College. Physiotherapy as an independent curriculum has existed only one decade in Estonia. At first (1990–1999) physiotherapy was taught as movement therapy in the University of Tartu, the Faculty of Exercise and Sport Sciences. In 1999, the exercise therapy curriculum was changed to curriculum of physiotherapy and since 2006 it is possible to study physiotherapy also on Master`s level. In Tartu Health Care College physiotherapy has been taught since 2001. During this period the curriculum has changed and developed remarkably due to the Process of Bologna.

According to the Process of Bologna in the University of Tartu four-year physiotherapy study (240 ECP) was changed to three-year study (180 ECP). Now the curriculum is assessed by external supervisors and national and international accreditation commissioners. Curricula in both schools have been fully accredited. After graduation (180 ECP) it is possible to find employment as a physiotherapist or continue the studies on Master`s level (120 ECP) at the University. Unfortunately, these studies are not made available for all applicants by the government (only 16 state-funded study places). In Europe generally it is not possible to work as a physiotherapist only after a three-year study. For example, in Norway it is compulsory to be placed in a practical training base one year after the three-year study period before getting the physiotherapy licence (N. Bugge Rigault, Oslo University College, personal contact, 2011).

Since 2005, 222 students have graduated from the physical therapy curricula in the University of Tartu and 150 from Tartu Health Care College (Table 1). Until now, there has been no specific feedback concerning the curriculum. Obtaining feedback is vital for further curriculum development. Thus, the aim of the study was to estimate how the physiotherapy students who have graduated from the University of Tartu assess the physiotherapy curriculum (theoretical knowledge, practical skills and generic competences) and how the curriculum has affected their professional preparation.

Table 1. The number of physiotherapy curriculum graduates in Estonia

Year of graduation	**University of Tartu**		**Tartu Heath Care College**
	Bachelor's Degree	**Master's Degree**	**Bachelor's Degree**
	Number of graduates		
2004			14
2005	23		13
2006	28		13
2007	30		16
2008	56	12	14
2009	24	15	25
2010	35	18	23
2011	26	10	32
Total	**222**	**55**	**150**

MATERIAL AND METHODS

Twenty-nine former students (females=25; males=4) participated in this study. The questionnaire was compiled based on the need to find out whether development is in accordance with the target group`s needs and what should be the directions chosen in further development. The questionnaire consisted of closed questions (multiple choice questions) to collect general information and open questions which required the respondent to reflect upon their opinion more thoroughly. All the participants filled in the anonymous questionnaire using the E-formular software.

RESULTS

Most of the respondents graduated from the University of Tartu in 2010. 82.2% of the participants had obtained the Bachelor's and 17.8% the Master's Degree. Approximately 80% of the participants work as physical therapists, mostly in hospitals (37.9%). Working places of the physiotherapists are presented in Table 2.

Table 2. Employments for physiotherapists.

Place to work	n	%
Hospital	11	37.9
Rehabilitation center	5	17.2
Private practice	3	10.3
Sports club	2	6.9
Special needs children school	1	3.4
Policlinic	1	3.4
Do not work as physiotherapists	2	6.9
Unemployed	4	13.8

According to the participants the strengths of the curriculum are:

- highly qualified professionals are included in the study process – all the teachers have at least a scientific Master's degree, most of them are well-known in-service training instructors;
- lecturers are also professional physical therapists – practical experience gives besides theoretical knowledge also practical knowledge and guarantees better quality of teaching;
- strong theoretical basis and versatile practical trainings in school and in clinical environment;
- modern practical training placements all over Estonia.

Weaknesses of the curriculum are:

- basic subjects are sometimes superficial and there is a lack of specialization – there is no time to study important subjects within the three-year study program;
- lack of external lecturers – lack of financial resources;
- connection between theory and practice is not always sufficient. Superficial theoretical knowledge may not always enable the students to perform their practical training successfully, and teaching methodology of a number of lecturers does not support outcome-based learning – the student-centred learning and teaching.

The curriculum offers basic knowledge, practical skills and generic competences (communication skills, teamwork, sense of duty) but there is a need to study more independently in study process and after graduation (in-service training). According to the participants` answers the last three-year developments of the curriculum are justified. Generally the curriculum is highly appreciated but there is a need for more international cooperation (external lecturers). In conclusion, 180 ECP are not enough to offer in-depth specialized knowledge and practical skills. According to this, there is a great need for studying further on Master level and/or special courses – lifelong learning.

There is a plan to organize similar questionnaires to develop the physiotherapy curriculum every spring with more students at the University in Tartu and also Tartu Health Care College and to use the standardized questionnaire “Development of professional attitudes among physiotherapy students during Bachelor degree programmes” [1, 2]. The questionnaire focuses on:

1. satisfaction with the physiotherapy degree programme (BA) and opinions on the curriculum of the programme;
2. perception of the physiotherapist’s profession;
3. opinions concerning undertaking employment as a physiotherapist as well as career plans;
4. personal data.

REFERENCES

1. Gotlib J., Bialoszewski D., Sierdziński J., Jarosz M.J., Majcher P., Barczyk K., Bajer K., Cabak A., Grzegorczyk J., Plaszewski M., Kulak W., Nowotny-Czupryna O., Prokopowicz K. (2010) A comparison of the perceptions and aspirations of third-year physiotherapy students trained in three educational settings in Poland. Physiotherapy. 96: 30–37
2. Gotlib J, Bialoszewski D, Kamińska I, Kunicka i, Sierdziński J. (2009) Familiarity with career possibilities among first-year physiotherapy students from Poland and Latvia – implications for curricula. Proceedings of the 10-th Congress of the European Federation for Research in Rehabilitation, Riga, Latvia, September 2009. Int. J. Rehabil. Res. 32 Suppl 1: 92–93

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THE ROLE OF PEERS: SIBLINGS AND FRIENDS IN THE RECRUITMENT AND DEVELOPMENT OF ATHLETES

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ABSTRACT

The role of peers (siblings and friends) in the recruitment and development of cross country skiers was investigated using quantitative methodology. A questionnaire, constructed according to a Likert format, was employed to collect data on the 350 highest ranked cross country skiers on the International Ski Federation (FIS) point list (gender not a factor) representing the Norwegian Ski Association (NSF), and the United States Ski and Snowboard Association (USSA). Approximately half the athletes were from each country. For the purpose of data analysis respondents were classified into three performance levels based on the best self-reported results from very high level ski competitions. The broad consequences of the findings of the study direct attention to the necessity of viewing sport not only in its individual talent/physiology/biomechanics/psychology dimensions but also in its societal contexts. More specifically, athletic performances may be viewed as significantly mirroring total growing-up conditions and life situations, particularly with reference to the intimate primary group relations of family and friends, and as such can be a measuring rod for the efficacy of a society's social facilitation and policies.

Key words: talent, skiing, peers, recruitment, development.

INTRODUCTION

A great deal of mythology has been spun about talent in sport. Generally the understanding of "talent" has been linked with genetic sources, much related to the idea of identifying talent already in childhood. Even today it is still argued that talents have been identified among children, as a forecast of future elite performers in sport. Despite the fact that some do succeed, the foundation for predicting this is thin. Neither personality nor identity are strongly anchored in the child as the basis for motivation and commitment, and neither is anything known of future resources for development in the interaction between personality and external access to resources. If the concept of talent is to be of use in serious dialogue and communication, then it is paramount that those involved have some commonality in their understanding of the term. In an attempt to clarify the issue, the following definition of talent is offered; a definition that guides the present work:

An athletic talent is characterized by the sporting achievements the individual has demonstrated as possessing the potential to reach, dependent on sufficient associated motivation, effort, and resources of varying type, size, and quality on an open-ended scale.

This means that there will always be discussion about the degree of talent. An unknown part of the talent's potential lies in the genes, whereof in many sports a number of concrete physiological parameters are known.

A highly talented performance level is, however, not only a result of inborn characteristics, but to the greatest degree a product of voluminous goal-directed training [8]. An optimization of this training is conditional on good motivation, great effort, and large resources of many kinds. The closely associated question then is how such motivation, effort, and resource-base emerge? While motivation and will to apply effort lie within the athlete, the resources needed are both of internal character in the athlete's personality, and of external character such as economy, knowledge, infrastructure, access to transport, equipment and materials of various types, etc. All these interact in dynamic fashion.

The absolutely fundamental condition for development of talent in sport is that the athlete–to-be is recruited to the athletic setting. This takes place in a social context composed of the family, and possibly a coach, in addition to the child [15]. The family's importance for the achievement of high performance-capacity has been in the spotlight in several studies including in a recent inquiry [13] where the parental role in the athlete socialization was investigated. The influence of siblings in the dynamics of the family is, however, a field that to a great extent has been overlooked in the study of sport. Although the same cannot be said of friends, even here there is a continued lack of a clear unraveling of their role.

From this point of departure, the following problem is addressed in the present investigation:

What role and consequence have siblings and friends in the recruitment and development of talents in the sport of cross country skiing?

The impetus for this query was the juxtaposition of several decades of intense experience by the authors with cross country skiing in Scandinavia and North America. How Scandinavia, in spite of its modest population, has historically dominated this sport, was a question that needed resolution. That there has not been a lack, in North America, of science-based knowledge of human performance variables, or a deficiency in technological competence or resources, was clear. *Au contraire,* reflection led to the socio-cultural arena in the search for answers, and in particular to the siblings within the family context, and beyond it to those significant others of children and youth, their friends. In Norway, success on the ski-trail has commonly been heavily viewed as an expression of socio-cultural forces, including politics and nation-building [4].

REVIEW OF THE LITERATURE

Role-models in the Socialization to and within Sport

If siblings and friends are felt as providing compelling demonstrations of inspiring behaviour, then children are drawn to identify with them. Through observation and acting like them, the children journey through a process of socialization towards a more anchored identity as an individual. Siblings and friends can through encouraging and rewarding behaviour in their settings together with other children and youth, contribute to constructive identity development. The study of such relationship dynamics formed the basis of the social-cognitive perspectives of Bandura [3]. The sum of habits, expectations, and interpretations of social contexts informed Bourdieu and Wacquant toward the concept of *"habitus"* (1992). The implication of this is that all that contributes to form the daily life of a family, such as social inheritance, social environment, relatives, and friends, will in sum connect the child to a culture or subculture. This is expressed through a familiar lifestyle of some form, and carries consequences for the relatively malleable children. It is therefore close at hand to expect a relationship between the athletic activities of siblings and friends in the recruitment of children to sport. It is suggested that this is an important element in forming the foundation for the further development of athletic talent.

Côté [7] proposed the existence of three defined stages in sport-participation; the "sampling years" (6–13), the "specializing years" (14–15), and the "investment years" (over 15). An important condition for taking care of recruited children and preventing their dropping out from sport during their first development phase has been the feeling of joy and fun in sport, and the experience of growing skill-mastery through minimizing competition-stress [7, 10]. In the "investment years", however, the child would connect to only one sport. Training loads then grow to be extreme and disciplined, with performance at the elite level as the objective.

The Role and Significance of Siblings

In an in-depth study of the most internationally successful Norwegian athletes (6), two out of three in the top performance group indicated that their siblings had great or some importance for their personal athletic career. As many as three of four, moreover, had siblings who had large or moderate involvement in sport. In the control group which had not progressed as far along the career path, only barely one of three placed large or moderate significance on siblings for their career. All subjects in both groups had one or more siblings. A large majority in both groupings was the youngest or next-to-youngest among the siblings in the family.

The large-scale investigation by Eriksson [9] of Swedish national team members did not inquire about the importance of siblings, but nevertheless found that 94% had one or more siblings. However, it did not appear to matter where in the sequence of siblings the subjects were located. The distribution among oldest, in the middle, or youngest, was fairly even. In one of the larger, multidisciplinary, sports it appeared that a little brother/little sister role could to some degree be advantageous since a clear majority of respondents was the youngest sibling (in families of multiple siblings).

In Côté's [7] study it was concluded that sibling influence changed in concert with that of the parents in the progression through the three phases in athlete development. Throughout the "sampling years", all children in the family received the same support from the parents. However, during the "specialization years", parental attention and resource allocation gradually shifted more towards the athlete(s) in the family. This process received such distinct reinforcement in the "investment years" that it in some instances resulted in jealousies and bitterness among younger siblings where present. Nevertheless, in some families, older siblings were found to have a positive influence on the young athlete's decision to specialize in a given sport. This confirms that the role of the family must perforce be complex due to the manifold possible familial configurations.

Stevenson [16], in yet another study, concluded that siblings became important for the athlete in the later phases of development. They acted so as to take over the parents' influence as role-models.

The Role and Significance of Friends

The role of friends in children's socialization to sport is better known. Less understood is their influence on the development of an athlete's capacity for high performance.

The number of friends and their role appears to alter through the stages of development of an athlete towards the elite level. Abernethy, Wood, and Parks [1] found in a study of members of 15 Australian elite teams that all had had a group of friends involved in sport, early in their career. However, the meaning of having friends outside, as well as inside, sport became at least equally important during the "investment years". Through friends in sport, a great and important common link was established, while friends outside sport provided acknowledgement and appreciation for the athletic effort, while they simultaneously contributed to meeting the athlete's need to talk about things outside sport. It could appear that friends outside sport contributed to covering more complex social needs.

Breivik and Gilberg [6] found that fewer of their elite athlete subjects had friends who were active in the same sport as themselves, compared with the control group. However, it was not always so for these very top level athletes. In the beginning, many of these also had friends in sport. But advancing from 10 to 20 years of age, they progressively had fewer friends in sport, while a stable proportion of the control group retained theirs. The number of elite athletes who had friends active in their sport, sank from 75% to 50% over these years, while in the control group the figure stayed quite stable at ca. 70%. Of the elite athletes, as many as two of three demonstrated considerable independence by indicating that they would continue with their sport regardless of whether their friends did or not. Still, concerning the importance their friends had for them, 61.1% of the elite placed large or some significance on their friends for their own personal continued effort in sport. Impressive as this effect of friends appears to be, it pales in comparison with the control group where fully 88.2% indicated their friends had large or some importance for their personal ongoing involvement in sport.

The research by Stevenson [16] showed that friends, like siblings, grew in influence in the later phases of athlete development, superseding the importance of parents.

In the Eriksson [9] study of the Swedish national team members, both parents and friends were main reasons why sport at all came into their life picture. However, here as well, it was the parents who were of consequence in the early period, while the friends relatively soon thereafter took over as the dominating causal social factor.

MATERIALS AND METHODS

Quantitative Method

A quantitative method through the use of questionnaire was employed due to the large number of subjects and their dispersed, international locations.

Selection of Respondents

The 350 highest ranked cross country skiers (gender not a factor) representing the Norwegian Ski Association (NSF), as well as of the United States Ski and Snowboard Association (USSA), were selected for the study, ca. half from each country. The selection criterion was placement on the International Ski Federation's (FIS) point list.

Access to Respondents

Personal relationship with the administrative head of the NSF was instrumental in gaining access to contact information for the Norwegian athletes. In the United States, the contact information for the skiers was gained through the National Team coach (personally known from Norway).

Questionnaire Construction

The questionnaire was constructed according to a Likert format [2, 11]. The content had its foundation in the more than 40 years of experience in cross country skiing of each of the authors of the study. The elements of this background were personal competition experience as well as extensive work in the coaching role and in providing technical expertise from the local to the international level, as well as tertiary degrees in sport science with substantial focus on skiing. Personal research background contributing to the study's questionnaire construction included the development of the Behavior Inventories for Cross Country Skiers [14].

The response alternatives were scored on a scale of zero to five, depending on the degree of agreement, with 1 indicating complete disagreement and 5, complete agreement.

It was decided to include a neutral response alternative (nr. 3) despite a possible "pole-effect" [12] whereby some respondents may have a disposition to choose the first or last alternative in Likert-type questionnaires. A neutral alternative can enhance study validity in that some subjects may, in fact, not be able to respond any other way. In addition, the inclusion of a neutral alternative makes it possible to score questionnaires where respondents leave some items unanswered. In such cases, these items are scored according to the neutral response alternative.

Original questionnaire language was Norwegian, and translation into American English was carried out according to established research practice.

Pilot Study

The questionnaire was administered to cross country ski coaches and elite athletes, as well as researchers familiar with the sport, in Northwestern USA, Canada, and Norway. As a consequence of constructive feedback, changes were made in question formulations.

The revised questionnaire was sent out again to the coaches and researchers for comment. These were then taken into account, and the final version was successfully tested on a university cross country ski team. Final layout modifications were suggested, and implemented.

Collection of Data

The questionnaire was distributed to 185 skiers in the USA and 165 skiers in Norway. Follow-up letters were sent two weeks later to those not yet responding.

Response Rate

The response rate in the USA was 57.8% (107 out of 185), and 65.5% in Norway (108 out of 165). Included among the respondents was 100% of the National Team in both countries.

Statistical analysis

The respondents were classified into three performance levels based on the best self-reported results from ski races at very high levels. Group 1 was composed of present and former National Team members with international high level performances. Group 2 skiers were below this performance level, while Group 3 was the lowest performing group.

This classification system resulted in the following athlete distribution among the three performance groups in the two countries:

	Group 1	**Group 2**	**Group 3**
USA	20	68	19
Norway	37	46	25

In the analysis of the data it was found to be appropriate for the purpose of clarity of result presentation and discussion to combine the response categories “Yes, I agree” with “Yes, I agree completely”, as well as “No, I disagree” with “No, 1 disagree completely”.

Quality Evaluation of the Study

Reliability and validity were enhanced by the careful process of instrument construction based on the authors' long-term experience and with the assistance of expert advice from practitioner and scientific personnel. The multi-phase pilot testing of the questionnaire ensured thorough assessment on an empirical basis. For a more exhaustive examination concerning the quality of the materials and methods of the investigation, the reader is directed to the authors' recent cognate publication (13) which, like the present inquiry, was part of a larger-scale project.

RESULTS

The results of the study are presented under headings replicating item formulations in the questionnaire. In addition to the presentation of separate data in table form for each country, there is associated textual description. The question numbers refer to the numeration in the omnibus questionnaire for the broader investigation.

1) **My siblings were involved in sport or cross country skiing in my childhood.**

In Norway as many as 77.8% of the skier respondents "agreed" or "completely agreed" with this statement. The figure for the United States was somewhat lower, at 68.2%.

Table 1a: Norway "In my childhood my siblings were engaged in cross country skiing" (question 3)

Likert scale points	**Completely disagree (1)**	**Dis-agree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Number of skiers	14	3	7	22	62	108
% of total number of skiers	13.0	2.8	6.5	**20.4**	**57.4**	100.0

Note: Percentage "agree" and "completely agree" in bold script are combined in the text.

Table 1b: USA "In my childhood my siblings were engaged in cross country skiing" (question 3)

Likert scale points	**Completely disagree (1)**	**Dis-agree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Number of skiers	25	1	8	26	47	107
% of total number of skiers	23.4	0.9	7.4	**24.3**	**43.9**	100.0

Note: Percentage "agree" and "completely agree" in bold script are combined in the text.

2) My siblings had great significance for my development as a cross country skier.

It should be noted that for this item, closely similar responses were given by the two countries on the "agreed/completely agreed" alternative; 34.2% in Norway, and 31.8% in the United States. However, the greatest density of responses was found among those reporting to "disagree" or to "completely disagree"; 47.2% in Norway and a substantially lower 38.4% in the United States. Those unsure ("neither agree nor disagree") were, in contrast, more numerous in the U.S., with 29.9%, compared to 18.5% in Norway.

In the performance group analysis, only 25.0% of Group 1 in the United States "agreed" or "completely agreed" with the statement, while over the double incidence (52.6%) of Group 3 skiers in that country responded in the same way. For Norway, the tendency is in the opposite direction, with 37.8% in Group 1, as contrasted to 28.0% of Group 3, reporting giving their siblings great significance. Unsure ("neither agree nor disagree") Group 1 athletes in the United States were as many as 35.0%, whereas in Norway, only 16.2% of Group 1 responded in this manner.

Table 2a: Norway "My siblings had great significance for my development as a cross country skier" (question 4)

Likert scale points	Completely disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Completely agree (5)	Total
Groups of skiers						
Group 1 (highest performance level): • number of skiers • % within group	12 32.4	5 13.5	6 16.2	6 **16.2**	8 **21.6**	37 100.0
Group 2 (lower level performers): • number of skiers • % within group	14 30.4	8 17.4	8 17.4	10 21.7	6 13.0	46 100.0
Group 3 (lowest performance level): • number of skiers • % within group	6 24.0	6 24.0	6 24.0	4 **16.0**	3 **12.0**	25 100.0
Total number of skiers	32	19	20	20	17	108
% of total number of skiers	**29.6**	**17.6**	**18.5**	**18.5**	**15.7**	100.0

Note: Percentage "agree/disagree" or "neither agree nor disagree" in bold script are combined for each group in the text.

Table 2b: USA "My siblings had great significance for my development as a cross country skier" (question 4)

Likert scale points	**Completely disagree (1)**	**Dis-agree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Groups of skiers						
Group 1 (highest performance level): • number of skiers • % within group	3 15.0	5 25.0	7 **35.0**	2 **10.0**	3 **15.0**	20 100.0
Group 2 (lower level performers): • number of skiers • % within group	16 23.5	13 19.1	20 29.4	7 10.3	12 17.6	68 100.0
Group 3 (lowest performance level): • number of skiers • % within group	3 15.8	1 5.3	5 26.3	7 **36.8**	3 **15.8**	19 100.0
Total number of skiers	22	19	32	16	18	107
% of total number of skiers	**20.6**	**17.8**	**29.9**	**15.0**	**16.8**	**100.0**

Note: Percentage "agree/disagree" or "neither agree nor disagree" in bold script are combined for each group in the text.

3) Several of my friends were engaged in cross country skiing in my childhood.

The proportion of those agreeing or completely agreeing with this statement is 64.9% in Norway, while in the United States it is lower, at 57.0%.

For Norway, the differences among the performance groups are minimal, while in the U.S., Group 1 stands out with its low score of 45.0% agreeing or completely agreeing. In contrast, in Norway, Group 1 ranks highest with a figure of 67.5% who "agree" or "completely agree".

Table 3a: Norway "Several of my friends were engaged in cross country skiing in my childhood" (question 5)

Likert scale points	**Completely disagree (1)**	**Dis-agree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Groups of skiers						
Group 1 (highest performance level): • number of skiers • % within group	4 10.8	2 5.4	6 16.2	10 27.0	15 40.5	37 100.0
Group 2 (lower level performers): • number of skiers • % within group	5 10.9	4 8.7	7 15.2	19 41.3	11 23.9	46 100.0
Group 3 (lowest performance level): • number of skiers • % within group	5 20.0	1 4.0	4 16.0	8 32.0	7 28.0	25 100.0
Total number of skiers	14	7	17	37	33	108
% of total number of skiers	13.0	6.5	15.7	**34.3**	**30.6**	100.0

Note: Percentage "agree/disagree" or "neither agree nor disagree" in bold script are combined for each group in the text.

Table 3b: USA "Several of my friends were engaged in cross country skiing in my childhood" (question 5)

Likert scale points	**Completely disagree (1)**	**Dis-agree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Groups of skiers						
Group 1 (highest performance level): • number of skiers • % within group	1 5.0	5 25.0	5 25.0	8 **40.0**	1 **5.0**	20 100.0
Group 2 (lower level performers): • number of skiers • % within group	10 14.7	10 14.7	8 11.8	20 29.4	20 29.4	68 100.0
Group 3 (lowest performance level): • number of skiers • % within group	3 15.8	2 10.5	2 10.5	7 36.8	5 26.3	19 100
Total number of skiers	14	17	15	35	26	107
% of total number of skiers	13.1	15.9	14.0	**32.7**	**24.3**	100.0

Note: Percentage "agree/disagree" or "neither agree nor disagree" in bold script are combined for each group in the text.

4) My friends have always given me recognition for my efforts in cross country skiing.

Almost as many in the United States (70.1%) as in Norway (67.6%) were in agreement or complete agreement on this statement. These figures represent more than the extent of ski-friends, especially in the USA, and suggest also friends outside sport. Separate performance group figures are not shown due to the great homogeneity of results both within and between the countries.

Table 4a: Norway "My friends have always given me recognition for my efforts in cross country skiing" (question 9)

Likert scale points	**Completely disagree (1)**	**Disagree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Number of skiers	1	7	27	**42**	**31**	108
% of total number of skiers	0.9	6.5	25.0	**38.9**	**28.7**	100.0

Note: Percentage "agree" and "completely agree" in bold script are combined in the text.

Table 4b: USA "My friends have always given me recognition for my efforts in cross country skiing" (question 9)

Likert scale points	**Completely disagree (1)**	**Disagree (2)**	**Neither agree nor disagree (3)**	**Agree (4)**	**Completely agree (5)**	Total
Number of skiers	0	5	27	**46**	29	107
% of total number of skiers	0.0	4.7	25.2	**43.0**	27.1	100.0

Note: Percentage "agree" and "completely agree" in bold script are combined in the text.

DISCUSSION

The Role and Significance of Siblings

When well over 3 out of 4 of the Norwegian skiers (77.8%) had siblings engaged in sport generally, and that among the U.S. skiers more than 2 of 3 (68.2%) grew up with siblings who were active specifically in cross country skiing, then it would be near at hand to interpret this as a factor leading to success. However, this does not coincide with the perception of the skiers. *Only approximately 1 of 3 maintains that their sibling(s) had great significance for their development as cross country skiers (34.2% in Norway and 31.8% in the U.S.).* Many more appear to have developed very well without significant sibling influence (47.2% in Norway, and 38.4% in the

U.S.A.). Although the 38.4% figure for the U.S indicates considerable independence, it pales in comparison with the 47.2% for Norway. It may well be that the difference in these figures finds its roots in cultural history whereby the development of skiers in the United States is more dependent on a sport-specific role-modelling of siblings in the micro-structure of the family, than in Norway, where the broader cultural anchoring of skiing carries an overarching significance. Notable, however, is that in Norway, the top performance group reports greater sibling impact (37.8%) than the other performance levels, whereas in the United States the converse is true, with the top group, at 25.0%, being the lowest. This finding supports the view that at the very highest performance level, siblings do play a positive role. Why such is not the case in the U.S. is a matter for further investigation.

The relatively low influence of siblings found here is not in agreement with the Breivik and Gilberg [6] study of Norwegian world elite athletes, *where 2 of 3 allocated great significance to their siblings for their athletic career.* Their control group, however, showed a pattern similar to the skiers in the present study. Of additional interest, broadly speaking, is that precisely the same proportion (77.8%) of the Breivik and Gilberg [6] elite had athletically active siblings, as was found among the Norwegian skiers in the inquiry at hand.

Intuitively there appears to be a contradiction between the athleticism of siblings and the perception of its importance by the skiers in the study. This finding calls for more detailed research on this question.

The Role and Significance of Friends

When well over half (57.0%) of the best cross country skiers in the United States, and close to two out of three (64.9%) in Norway, had friends in cross country skiing, then this points itself out as an important socialization factor. The friendship group may be viewed as a bearer of the culture of cross country skiing. In view of the Norwegian data on the separate performance groups it was conspicuous that in the U.S. Group 1 only 45.0% had childhood skiing friends, while the Group 2 figure was 58.8%, and for Group 3 it was 63.1%. For Norway, not only were the group differences smaller; they were in the opposite direction (Group1: 67.5%, Group 2: 65.2%, and

Group 3: 60.0%). That the Norwegian figures, in general, were higher was expected in view of the greater degree of participation in cross country skiing in Norway. However, to explain the contrary group patterns in the two countries more detailed inquiries are required. It remains to be noted, however, that the highest figure recorded was for the highest performance skiers in the study, Norwegian Group 1, and that this lends credence to the suggestion that this ski-social setting in childhood was not without its constructive impact.

Concerning friends' recognition of the efforts in the sport by the skiers in the study, the figures from the two countries do not vary a great deal. In the overall data, 67.6% of the Norwegian skiers confirm such recognition, while 70.1% of the U.S. skiers do so as well. It may be assumed that such recognition has had a positive effect for further efforts, and in this regard the figures reported may be favorably compared with those of Breivik and Gilberg [6] in their study of world elite Norwegian athletes. They found that 61.1% of their subjects assigned significant impact to their friends for their continued efforts in their sport. The athletes in that study could, performance-wise, best be compared with the top groups in the present study, and particularly with the Norwegian Group 1. In this group, as many as 72.9% (for the U.S., 70.0%) reported the appreciation of their friends. The feed-back of friends may thus be seen as a notable factor in the athletic life-context of high-level cross country skiers.

CONCLUSIONS

The results of the parents' status, role, and engagement [6] were shown to have in decisive terms contributed to the creation of what has been termed *"athlete families"*. The confirmation of this is found not only in the high level skiers in the study, but also in the general sport- and ski-specific involvement of siblings. Almost 2 of 3 of the best skiers in the U.S. and Norway, respectively, have siblings who were involved in sport generally or cross country skiing specifically. When, nevertheless, only 1 of 3 in each country assign importance to siblings in their own development as skiers, then questions arise. It is possible that some important psycho/social influences had not been consciously registered; -however in-depth interviews would be required for this to be examined. The Breivik and Gilberg [6] interview study of the very best Norwegian athletes did indicate that far more (2 of 3) indicated that their siblings had had considerable influence. In any case, other investigations concerning the role of siblings in sport show such divergent findings that, as Côté [7] points out, it is incumbent upon the field to pursue further clarification of family dynamics in the athletic arena.

Friends are outside the family, but may still have such an important daily presence that their influence can be expected to have significance. Approximately 6 of 10 respondents in the two countries had friends in childhood who were involved in cross country skiing. In vicinity of two thirds had friends who always acknowledged their efforts in cross country skiing. *Of these, about one third of friends in both countries were from outside the sport.* This was an unexpected finding, indicating that further research is called for to unravel the implications for skiers of these different friendship groups.

The attention paid to friends in sport has been considerably more extensive in earlier studies than that devoted to the role of siblings, notwithstanding that both groupings represent age-mates, or close to it, in the athlete's intimate circle. In the present sphere of investigation, however, the perspectives and findings remain so diverse that is difficult to extract a clear picture. Future work is necessary to shed light on this sector of the athlete's social context. The present study finds only partial confirmation in the relatively comparable Breivik and Gilberg (6) Norwegian world elite investigation, in the way of a reasonable correspondence *vis-à-vis* the acknowledgement of friends and its importance for the athletic career.

The broad consequences of the recognitions of the present study direct attention to the necessity of viewing sport in its societal contexts. More specifically, athletic performances may largely be seen as mirroring the total growing-up condition and life situation, and as such can be a measuring rod for a society's social policies. With a well-organized and child/youth-friendly political and economic system, a society will facilitate both broad athletic participation as well as performances at the very highest levels. As evident as this is, it nevertheless must also be recognized that for peak achievements to be reached, sport-specific facilities and organizations, as well as highly educated and experienced coaches are needed.

Although the inquiry at hand supports the findings of other studies referred to and thus strengthens the understanding of the role of the sociological 'primary group' in sport, future investigations in this realm could with advantage focus on other sports with a variety of different demands in order to delineate possible sport-specific elements of value in the socialization process of aspiring youngsters. An additional and complementary approach would be to broaden the international comparative perspective to uncover further socio-cultural underpinnings that may be of importance in the developmental voyage of ambitious young athletes.

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REFERENCES

1. Abernethy B., Wood J. M., Parks S. (1999) Can anticipatory skills of experts be learned by novices? Res. Q. Exerc. Sport. 70: 313–318
2. Babbie E. (1973) Survey research methods. Florence: KY: Wadsworth
3. Bandura A. (1986) Social foundations of thought and action: A social cognitive theory. Upper Saddle River: NJ: Prentice-Hall
4. Bomann-Larsen T. (1993) Den evige sne: En skihistorie om Norge. Oslo: Capellen
5. Bourdieu P., Wacquant L. J. D. (1992) An invitation to reflexive sociology. Chicago: University of Chicago Press
6. Breivik G., Gilberg R. (1999) Hvorfor de beste ble best? Oslo: Norges Idrettshøgskole.
7. Côté, J. (1999). The influence of the family in the development of talent in sport. The Sport Psychologist. 13: 305–417.
8. Ericsson K. A., Krampe A. T., Tesch-Römer C. (1993) The role of deliberate practice in the acquisition of expert performance. Psychol. Rev. 3: 363–406
9. Eriksson S. (2001) Vägen till A-lanslaget. In: Sweden: SVEBI's årsbok Aktuell Beteende- och Samhällsvetenskaplig Idrottsforskning
10. Hellstedt J. C. (1987) Invisible players: A family system model. (1995). In: Sport Psychology Interventions. S. M. Murphy (ed.). Champaign, ILL: Human Kinetics. 117–146
11. Likert R. (1932) A technique for the measurement of attitudes. Archives of Psychology. 22
12. Mordal T. (1989). Som man spør får man svar. Oslo: Tano

13. Rønbeck N.- F., Vikander N. O. (2010) Select your parents with care! – The role of parents in the recruitment and development of athletes. Acta Kin. Univ. Tartuensis. 15: 62–100
14. Rushall B. S., Vikander N. O. (1987) Behavioral inventories for cross country skiers. Spring Valley, CA: Sports Science Associates
15. Scanlan T. K., Lewthwaite R. (1988) From stress to enjoyment: Parental and coach influences on young participants. In: Competitive sports for children and youth: An overview of research and issues. E. W. Brown, C. F. Branta, (eds.). Champaign, ILL: Human Kinetics. 47–58
16. Stevenson C. L. (1990) The early careers of international athletes. Sociol. Sport J. 7: 238–253

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KNEE PAIN AND POSTURAL STABILITY IN WOMEN WITH GONARTHROSIS BEFORE AND SIX MONTHS AFTER UNILATERAL TOTAL KNEE REPLACEMENT

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ABSTRACT

The aim of this study was to investigate knee pain and postural stability in women with knee osteoarthritis (OA), who used postoperative home exercise program (HEP) with balance exercises. 14 women with knee OA in stage III–IV (aged 48–70 years) participated in this study before and 6 months after unilateral total knee arthroplasty (TKA). All patients performed HEP during 6 months after unilateral TKA. Data of patients was compared with healthy age-matched women (controls, n=10). Postural stability characteristics (centre of pressure (COP) displacement in the anterior-posterior (AP) and mediolateral (ML) direction, COP sway equivalent radius and area) during 30 s bipedal standing (eyes open) were recorded on two dynamographic force plates. Pain in knee joint was estimated with visual-analogue scale. COP displacement in AP direction of the operated and non-operated leg was greater ($p<0.05$) in women with knee OA before and 6 months after TKA compared to the controls. Knee joint pain in the operated leg reduced 70% after TKA. TKA together with HEP has an important role in preserving postural stability and reducing knee joint pain in women with III–IV stage gonarthrosis.

Key words: knee osteoarthritis, static balance, postural sway, rehabilitation.

INTRODUCTION

Osteoarthritis (OA) is the most common joint disease worldwide [18] that appears to originate in the cartilage and affects the underlying bone, soft tissues, and synovial fluid and is mostly affecting the hand and large weight-bearing joints such as the knee [5]. It is particularly disabling when the knees are affected, because it limits the ability to walk, to rise from a chair, and to use stairs [8].

One of the main indications of knee joint OA is pain that is incompatible with normal daily living and that does not respond to conservative treatment [10]. Patients with greater preoperative pain have more postoperative pain [2]. Hassan et al. [11] observed that knee joint pain and quadriceps strength were significant predictors of increased postural sway. Women who reported widespread pain had a 60% greater risk of falling compared to women with no or mild pain [17].

Balance is an integral component of many activities of daily living [12]. It has been found that compared with healthy subjects, patients with knee joint OA have poor postural stability, which is associated with a decrease in functional performance [14]. Pain and muscle strength may particularly influence postural sway [11]. Impairments in knee joint proprioception have been mentioned by multiple authors [11, 14, 21]. These deficits, in combination with the ageing process, may culminate in greater impairments of balance in this patient population, compared with their age-matched and healthy counterparts [12].

Total knee arthroplasty (TKA) is the most common treatment for stage III-IV gonarthrosis [16]. Patients with TKA also have impaired balance and movement control [19]. Osteoarthritis pathology and TKA appear to alter the proprioceptive function of the knee [6] as well as soft-tissue release during total knee replacement [1]. Changes in the proprioceptive function of the knee joint may contribute to altered balance control during standing and walking [6].

Study of Piva et al. [19] was to determine the feasibility of balance exercise program in patients with TKA. They found that improvement was higher for gait speed, single-leg stance time, and knee joint stiffness. Research of home exercise programs with prevalence of balance exercises to improve postural stability in women with gonarthrosis has not been enough elucidated in literature. The aim of the present study was to (1) investigate postural stability and knee joint pain in women with gonarthrosis who used postoperative home exercise program (HEP) with balance exercises before and 6 months after unilateral TKA and to (2) analyze the relationship between these parameters and (3) compare the results with healthy age-matched controls.

MATERIALS AND METHODS

Subjects

14 women (mean age 60.2, SE±2.0 years; mean body mass 88.6, SE±3.6 kg; mean height 160.0, SE±1.5 cm; mean BMI 34.7, SE±1.4) with knee OA in stage III-IV by Kellgren and Lawrence [16] and 10 healthy women (controls, mean age 59.5, SE±2.1; mean body mass 66.9, SE±3.8 kg; mean height 160.0, SE±2.0 cm; mean BMI 26.7, SE±1.6) participated in this study. The patients were operated at Tartu University Hospital. A condylar prosthesis GEMINI (W. Link Gmbh and Co., Germany) was used and seven out of 14 subjects underwent right knee TKA. Average duration of knee joint pain was 6.5 years. Each patient received a home exercise program (HEP) which contained knee range of motion exercises, strengthening and stretching exercises [4], movement control exercises, balance exercises and coordination exercises [13]. Additionally walking, bicycling and swimming were recommended. Each subject filled out an exercise diary.

Control group included 10 healthy age-matched women, who were not diagnosed with gonarthrosis and were moderately physically active.

Criteria for excluding subjects from both groups were: other musculoskeletal diseases, neurological diseases and diseases effecting balance and coordination. All of the subjects signed a written consent to participate in the study voluntarily. Ethics Committee of the University of Tartu approved the study. The research was conducted at the Laboratory of Kinesiology and Biomechanics of University of Tartu from September 2009 to March 2011. Patients participated in the study twice (1 day before surgery and 6 months after surgery), controls once.

Measures

For postural stability assessment subject was asked to stand on two dynamographic force plates Kistler 9286A (Szwitserland) during 30 seconds with right and left leg on different platform (distance between feet was 20 cm) and eyes open. Following body sway characteristics were recorded by movement analysis system Elite Clinic and SWAY® software (BTS S.p.A.): (1) COP sway displacement in the anterior-posterior (AP) (mm) and mediolateral (ML) (mm) direction; (2) COP equivalent radius (mm) and COP equivalent area (mm^2). All of the characteristics were normalized to the subject's height (m) and foot length (mm) [3].

Knee joint pain was assessed by visual-analogue scale (VAS) in both legs, where 0 – pain is absent and 10 – maximal pain.

Statistical analysis

Data is presented by means and standard errors (SE). Student paired *t*-test of MS Excel software was used to analyze the differences between pre- and postoperative results and unpaired *t*-test for differences between patients and controls and patients' operated and non-operated leg. Relationship between knee joint pain and postural stability was found by Spearman's rank correlation. P values < 0.05 were regarded as statistically significant.

RESULTS

Knee joint pain

Knee joint pain (Figure 1) in the operated leg of women with gonarthrosis was significantly higher compared to the non-operated leg as well to controls before TKA ($p<0.001$) and after TKA ($p<0.05$). Pain in the operated leg was significantly lower after TKA ($p<0.001$) compared to the preoperative state.

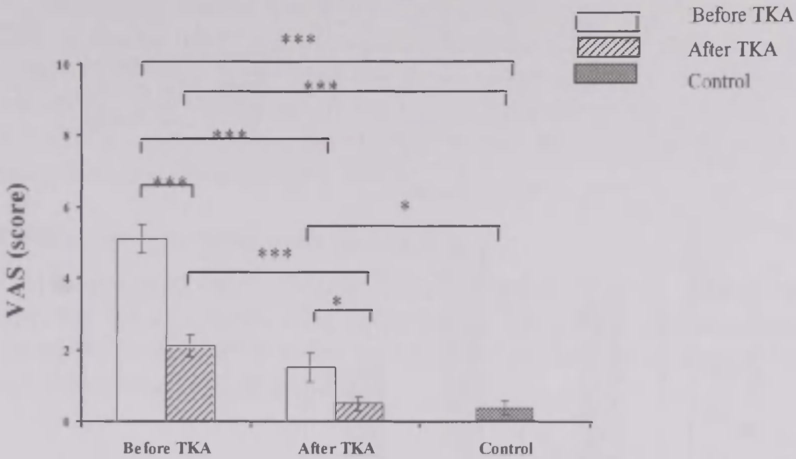

Figure 1. Knee pain in women with gonarthrosis before and 6 months after TKA compared to healthy controls (average of both legs) (mean±SE). ***p<0.001; *p<0.05.

COP displacement

COP displacement characteristics in AP direction (COP AP) (Figure 2A) on the operated leg in women with gonarthrosis were greater compared to the non-operated leg before TKA, but the difference was not statistically important. The results in the operated leg were significantly greater compared to controls (p<0.01). A tendency of improvement (decrease) in COP AP results in patients' operated leg compared to preoperative status was noted 6 months after TKA. This characteristic of the operated leg after TKA was significantly greater compared to controls (p<0.01).

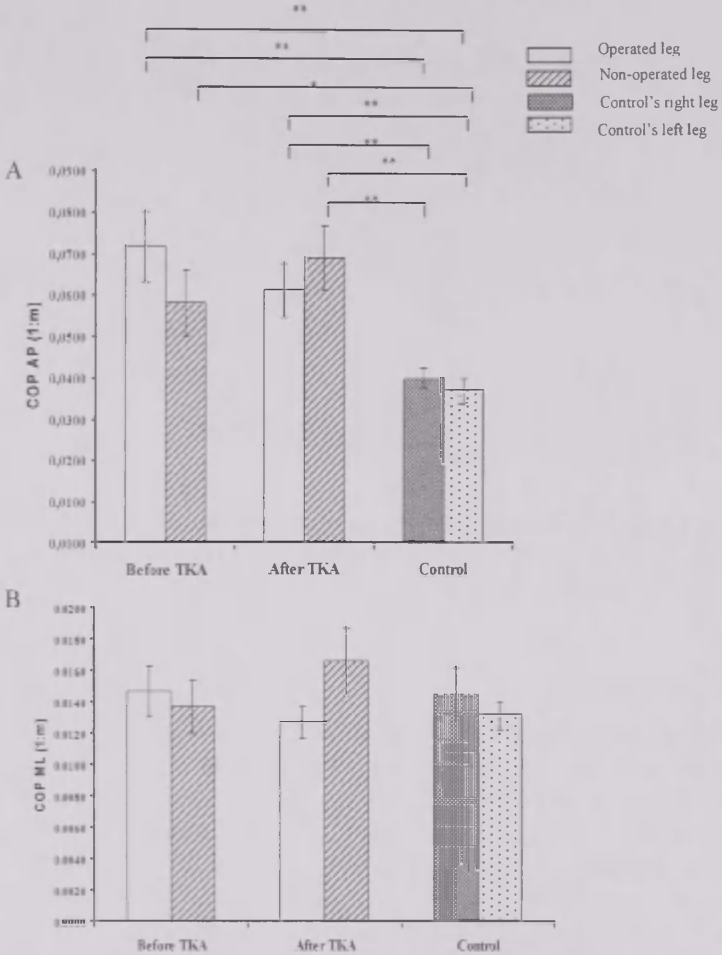

Figure 2. COP sway displacement in anterior-posterior (AP) (A) and mediolateral (ML) direction (B) in women with gonarthrosis before and 6 months after TKA compared to healthy controls (mean±SE). Data normalized to subjects height (m) and foot length (mm). ** $p>0.01$; * $p>0.05$

COP displacement in AP direction of patients' non-operated leg were significantly greater ($p<0.05$) compared to controls preoperatively and postoperatively.

Increase of COP displacement in ML direction (COP ML) (Figure 2B) of the operated leg in patients group was preoperatively noted compared to the non-operated leg and controls, but the difference was not statistically significant. A tendency of improvement (decrease) in this characteristic of the operated leg was found 6 months after TKA compared to the preoperative results.

COP sway equivalent area and radius

COP equivalent area (Figure 3A) and radius (Figure 3B) of the operated leg in women with gonarthrosis was preoperatively greater compared to the non-operated leg and controls, but the difference was not statistically significant.

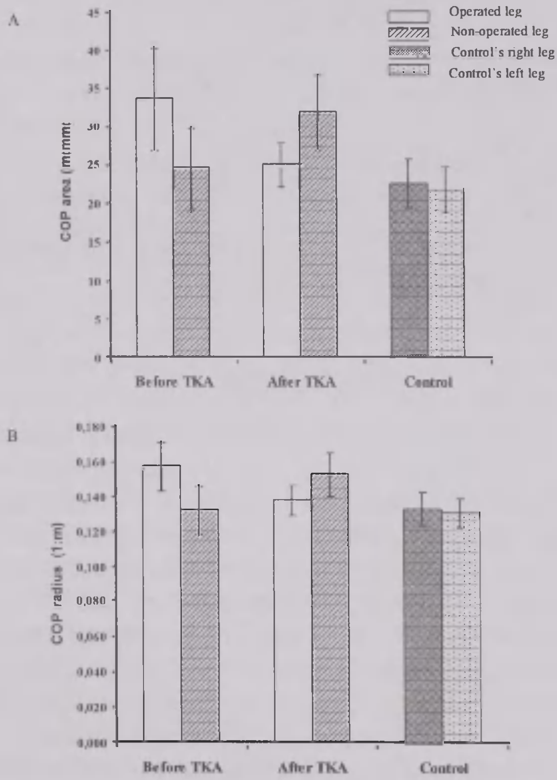

Figure 3. COP sway area (A) and radius (B) in women with gonarthrosis before and 6 months after TKA compared to healthy controls (mean±SE).

A tendency of improvement (decrease) in COP equivalent area and radius characteristics of the operated leg was found 6 months after unilateral TKA compared to the preoperative results. COP sway area and radius of the operated leg were greater compared to the controls, but the difference was not statistically significant.

Correlation

A medium negative correlation (p>0.05) was found between knee pain and postural stability characteristics (Table 1).

Table 1. Correlations between knee joint pain and operated leg's postural stability characteristics in women with gonarthrosis before and six months after unilateral total knee arthroplasty.

Characteristics	Pain	p
COP AP before TKA	0.17	NS
COP ML before TKA	-0.31	NS
COP AP after TKA	-0.47	NS
COP NL after TKA	-0.46	NS

COP – centre of pressure, AP – anterior-posterior, ML – mediolateral, TKA – total knee arthroplasty, NS – not significant.

DISCUSSION

Main results of the present study were: (1) postural stability (COP displacement in AP direction) of the operated and non-operated leg in women with knee OA is impaired before and 6 months after TKA compared to the controls, (2) negative moderate correlation (p>0.05) was noted between knee joint pain and postural stability characters, (3) six months after TKA it is possible to assume that TKA together with home exercise program may conduce to postural stability preservation and knee joint pain reduction in women with gonarthrosis.

OA is the leading chronic condition in the elderly; it affects almost half the population over 65 years old. Joint replacement is the most effective healthcare measure in improving patient quality-of-life outcomes. The need for joint replacements will increase as the population ages [10].

Compared with age and sex matched controls, subjects with symptomatic knee OA have quadriceps weakness, reduced knee proprioception, and increased postural sway (increased lateral sway with eyes open and increased lateral and anterior-posterior sway with eyes closed) [11]. The present study demonstrated that postural stability characteristics in AP direction were significantly greater in women with gonarthrosis compared to healthy controls. No difference was found between operated and non-operated leg data of COP equivalent area and radius in women with gonarthrosis.

Significantly greater sway in the OA group on a firm surface in ML direction has been previously found (eyes open) [12, 13]. In the present study ML sway decreased 13.4% after TKA compared to the preoperative result. AP sway of the operated leg decreased 14.8% after TKA compared to the preoperative result yet was greater compared to the controls (preoperatively 33.9%, postoperatively 22%).

In the present study it was found that COP area of the operated leg decreased 25.6% after TKA but was greater compared to the controls (preoperatively 32.6%, postoperatively 9.5%). COP radius of the operated leg decreased 12.4% after TKA but was greater compared to the controls (preoperatively 15%, postoperatively 3%). So it is possible to say that COP area and radius of the patients' operated leg restored to the level close to control group. Tarigan with colleagues [21] found an increase in length of postural sway, postural sway velocity and area of postural sway in patients with knee OA compared with healthy subjects. Swanik et al. [20] found that TKA results in improvements in proprioception and balance and that postural stability improved 6 months after TKA compared to the preoperative results.

Knee pain is one of the main complications after TKA [7]. In the present study we found that postoperative knee joint pain was reduced by 70% compared to the preoperative knee joint pain. Brander et al. [2] found that 18.4% of patients suffer from pain 6 months after TKA. In the present study a significant association between knee pain and postural stability characteristics was not found, but several studies have also suggested an association between knee pain and standing postural instability [9, 11]. Based on the present study it is possible to speculate that greater knee joint pain in patients with OA who also have flexion contracture may lead to greater postural sway. Also some other characteristics may influence postural stability, such as muscle strength [11].

Deficits in components of the balance system and decreased postural control have been identified in OA patients after TKA [20]. Therefore, exercises which aim to improve impaired movement control and balance should be considered in OA patients after TKA [19]. It is possible to conclude that TKA along with HEP may conduce to postural stability preservation and knee joint pain reduction in women with gonarthrosis. The effectiveness of home exercise program has also been found by Jordan et al. [15]. Further studies are necessary to recognize whether postural stability impairments are permanent in women with gonarthrosis or will improve few years after TKA.

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REFERENCES

1. Attfield S. F., Wilton T. J., Pratt D. J., Sambatakakis A. (1996) Soft-tissue balance and recovery of proprioception after total knee replacement. J. Bone Joint Surg. Br. 78: 540–545
2. Brander V. A., Stulberg S. D., Adams A. D., Harden R. N., Bruehl S., Stanos S. P., Houle T. (2003) Predicting total knee replacement pain: a prospective, observational study. Clin. Orthop. Relat. Res. 416: 27–36
3. Chiari L., Rocchi L., Cappello A. (2002) Stabilometric parameters are affected by antropometry and foot placement. Clin. Biomech. (Bristol, Avon). 17: 666–677
4. Deyle G. D., Allison S. C., Matekel R. L., Ryder M. G., Stang J. M., Gohdes D. D., Hutton J. P., Henderson N. E., Garber M. B. (2005) Physical therapy treatment effectiveness for osteoarthritis of the knee: a randomized comparison of supervised clinical exercise and manual therapy procedures versus a home exercise program. Phys. Ther. 85: 1301–1317

5. Flugsrud G. B., Nordsletten L., Reinholt F. P., Risberg M. A., Rydevik K., Uhlig T. (2010) Osteoarthritis. Tidsskr. Nor. Laegeforen. 130: 2136–2140
6. Gage W. H., Frank J. S., Prentice S. D., Stevenson P. (2007) Organization of postural responses following a rotational support surface perturbation, after TKA: sagittal plane Rotations. Gait. Posture. 25: 112–120
7. Garrett B. R., Walters J. (2010) Knee pain, swelling and stiffness after total knee replacement: a survey of South African knee surgeons. SAOJ. 59–66
8. Gür H., Cakin N. (2003) Muscle mass, isokinetic torque, and functional capacity in women with osteoarthritis of the knee. Arch. Phys. Med. Rehabil. 84: 1534–1541
9. Hall M. C., Mockett S. P., Doherty M. (2006) Relative impact of radiographic osteoarthritis and pain on quadriceps strength, proprioception, static postural sway and lower limb function. Ann. Rheum. Dis. 65: 865–870
10. Hart J. A. (2004) Joint replacement surgery. Med. J. Aus. 180 (5 Suppl): S27-S30
11. Hassan B. S., Mockett S., Doherty M. (2001) Static postural sway, proprioception and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann. Rheum. Dis. 60: 612–618
12. Hinman R. S., Bennell K. L., Metcalf B. R., Crossley K. M. (2002) Balance impairments in individuals with symptomatic knee osteoarthritis: a comparison with matched controls using clinical tests. Rheumatology (Oxford). 41: 1388–1394
13. Hurley M. V. (2003) Muscle dysfunction and effective rehabilitation of knee osteoarthritis: what we know and what we need to find out. Arthritis Rheum. 49: 444–452
14. Hurley M. V., Scott D. L., Rees J., Newman D. J. (1997) Sensorimotor changes and functional performance in patients with knee osteoarthritis. Ann. Rheum. Dis. 56: 641–648
15. Jordan K. M., Arden N. K., Doherty M., Bannwarth B., Bijlsma J. W., Dieppe P., Gunther K., Hauselmann H., Herrero-Beaumont G., Kaklamanis P., Lohmander S., Leeb B., Lequesne M., Mazieres B., Martin-Mola E., Pavelka K., Pendleton A., Punzi L., Serni U.., Swoboda B., Verbruggen G., Zimmerman- Gorska I., Dougados M. (2003) EULAR recommendations 2003: An evidence based approach to the management of knee osteoarthritis: report of a task force of the standing committee for international clinical studies including therapeutic trials (ESCISIT). Ann. Rheum. Dis. 62: 1145–1155

16. Kellgren J. H., Lawrence J. S. (1957) Radiological assessment of osteoarthritis. Ann. Rheum. Dis. 16: 494–502
17. Mandeville D., Osternig L. R., Chou L. S. (2008) The effect of total knee replacement surgery on gait stability. Gait Posture. 27: 103–109
18. Michael J. W., Schlüter-Brust K. U., Eysel P. (2010) The epidemiology, etiology, diagnosis, and treatment of osteoarthritis of the knee. Dtsch. Arztebl. Int. 107: 152–162
19. Piva S. R., Gil A. B., Almeida G. J., DiGioia A. M. 3rd., Levison T. J., Fitzgerald G. K. (2010) A balance exercise program appears to improve function for patients with total knee arthroplasty: a randomized clinical trial. Phys. Ther. 90: 880–894
20. Swanik C. B., Lephart S. M., Rubash H. E. (2004) Proprioception, kinesthesia, and balance after total knee arthroplasty with cruciate-retaining and posterior stabilized prostheses. J. Bone Joint Surg. Am. 86-A: 328–334
21. Tarigan T. J., Kasjmir Y. I., Atmakusuma D., Lydia A., Bashiruddin J., Kusumawijaya K., Prihartono J. (2009) The degree of radiographic abnormalities and postural instability in patients with knee osteoarthritis. Acta Med. Indones. 41: 15–19

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EFFECT OF HOME EXERCISE PROGRAMME ON THIGH MUSCLE STRENGTH BEFORE TOTAL KNEE ARTHROPLASTY

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ABSTRACT

The aim of the study was to assess the effect of home exercise programme (HEP) on thigh muscle strength in patients with knee osteoarthritis (OA) before unilateral total knee arthroplasty (TKA).

Five femaleOA patients with mean age 67.8±5.9 years participated in the study. Isometric maximal voluntary contraction (MVC) force of the quadriceps femoris (QF) and hamstring (HM) muscles was measured by hand-held dynamometry. Knee active range of motion (aROM) in flexion was measured by goniometer. Knee pain score was evaluated by knee pain scale before and after HEP.

A significant reduction ($p<0.05$) in MVC force of the QF and HM muscles and aROM in flexion were noted before HEP, comparing the involved and uninvolved leg. After HEP, MVC force of the QF muscle increased significantly ($p<0.05$) for the involved and uninvolved leg, whereas no significant differences ($p>0.05$) were observed between the limbs. MVC force of the HM muscle and aROM in flexion remained significantly lower ($p<0.05$) for the involved leg as compared with the uninvolved leg after HEP. Knee pain score was significantly ($p<0.05$) higher for the involved leg before and after HEP as compared with the uninvolved leg.

Two months before the operation, HEP was an effective therapeutic procedure for increasing QF muscle strength in patients who underwent TKA.

Key words: osteoarthritis, home exercise programme, isometric maximal voluntary contraction force, aROM

INTRODUCTION

Osteoarthritis (OA) is one of the most common chronic degenerative joint disorders and the prevalence increases with age throughout the elderly years [5]. Patients with OA have the pain that typically worsens with weight bearing and activity and improves with rest, as well as morning stiffness and swelling of the involved joint after periods of inactivity. On physical examination, they often have tenderness on palpation, bony enlargement, crepitus on motion, and/or limitation of joint motion [15]. Stefanic et al. [22] have demonstrated that the prevalence of lateral and medial patellofemoral joint cartilage damage and bone marrow lesions was higher in weaker compared to stronger knees. Ikeda et al. [7] suggest the possibility that age-related quadriceps-dominant muscle atrophy can play a role in the pathogenesis of knee OA. Segal et al. [19] concluded that in women but not in men, quadriceps muscle weakness appears to increase the risk of joint space narrowing over 30 months in the Multicenter Osteoarthritis study. Bade et al. [1] measured changes in muscle strength, range of motion, and function from 2 weeks before to 6 months after total knee arthroplasty (TKA) and compared them with data from healthy older adult control group. They found that patients performed significantly worse at all times for all measures as compared to healthy older adults. Mizner et al. [12] hypothesized in their study that preoperative quadriceps muscle strength is the best predictor of postoperative functional ability, compared to preoperative pain or knee range of motion (ROM). They concluded that preoperative quadriceps muscle strength plays a dominant role in predicting one-year Stair Climbing Test (SCT) and Timed Up and Go Test (TUG) functional measures, but it is not a good predictor of the score on self-report questionnaires. Preoperative body pain and knee flexion ROM are poor predictors of all functional outcome measures. Pertella [14] asked in her review article whether exercise is an effective treatment for osteoarthritis of the knee, and found that exercises had short-term effects in the treatment of patients with OA. Rodgers et al. [17] compared preoperative physiotherapy group with controls. The assessment included: Hospital for Special Surgery knee rating scale, knee range of motion, thigh circumference, walking speed, isokinetic knee flexion and extension testing, and computed tomography scanning for cross-sectional muscle area. They found that this study failed to support the routine use of preoperative physical therapy in knee replacement surgery. Jaggers et al. [9] investigated 4-week pre-rehabilitation in two women who underwent TKA. The functional outcome included a 6-minute walk test, the number of times of getting up from a chair in 30 s, proprioception, and self-reported function and pain estimation using the Western Ontario and McMaster University Osteoarthritis Index. They concluded that 4-week pre-rehabilitation had a positive effect on functional task performance and knee proprioception before surgery.

The aim of the current study was to assess the effect of home exercise programme in patients with knee OA on thigh muscle strength before unilateral total knee arthroplasty.

It was hypothezised that isometric maximal voluntary contraction (MVC) force of the QF and HM muscles, and aROM in flexion can be improved in patients with knee OA after 2-month preoperative therapeutic exercise programme, conducted at home.

METHODS

Subjects

Five female patients with OA aged 59 to 74 years undergoing TKA for III–IV stage knee OA participated in this study. The mean±SE age of the patients was 67.8±2.7 years, height 159.4±2.5 cm, body mass 74.7±5.8 kg, and BMI 29.4±1.9 kg/m^2. The subjects were recruited by orthopedic surgeons in the Department of Orthopaedics and Traumatology of Tartu University Hospital, between February and June 2011. The exclusion criteria included inflammatory arthritis, obesity (BMI>30 kg/m^2), implantated pacemakers, progressive neurological disease, diabetes, head injuries, cardiological diseases NYHA III-IV, osteoporosis, deep vein thrombosis, COPD. The study carried the approval of the Tartu University Ethics Committee.

Home exercise programme (HEP)

The preoperative therapeutic HEP was mainly oriented to muscle strengthening exercises with elastic band (Thera-Band, System of Progressive Exercise, US), and stretching, balance, and walking exercises. At the first meeting the physiotherapist taught the exercise programme to the patients, gave them the elastic band set, the printed exercise programme with pictures and explanations, and diary. The patients recorded every day several data in their diary – for how many times they did each exercise, the training time, perception of pain before and after HEP, time spent in outdoor walking, and the number of stairs walked during the day. Once a week the physiotherapist called the patients on the phone, and asked them about HEP and problems with the knee. The patients performed the exercises for 64 days on the average, whereas one patient did the exercises twice a day.

Isometric maximal voluntary contraction force

Isometric MVC force of the QF and HM muscles was measured by hand-held dynamometer (Lafayette Manual Muscle Test System). During QF muscle isometric strength testing the subject was in the seated position on an investigation bed with knee and hip flexed to 90 deg. Hand-held dynamometer was placed proximal to the ankle on anterior surface of leg. During HM muscle isometric strength testing, the subject was in the prone position. Hand-held dynamometer was placed proximal to the ankle on posterior surface of leg [2, 10]. The positions were supervised by the investigator and the subjects were encouraged to act in the desired way. The subjects were required to exert isometric MVC force pushing against the dynamometer for approximately 3 s before each contraction, and instructed to "push as hard as possible". The best results from 3 attempts were taken as isometric MVC force. A rest period of 1 min was allowed between attempts.

Stark et al. [21] wrote a systematic review on hand-held dynamometry correlation with gold standard isokinetic dynamometry and found that the research results demonstrated minimal differences between hand-held dynamometry and isokinetic testing.

Knee flexion range of motion measurement

Knee flexion aROM was collected in prone position using the standard long arm goniometer. The axis of the goniometer was placed over the lateral femoral epicondyle. The proximal end of the goniometer was aligned with the great trochanter of the femur and the distal arm was aligned with the lateral malleous. During knee flexion aROM measurement, the subjects were instructed to maximally flex the knee and draw the heel toward the buttocks. The average peak knee flexion was recorded from three trials. Goniometric knee flexion measurements are highly reliable in persons with knee OA [4].

Pain assessment

Self-assessment of knee pain in everyday activities was provided by reports on 10-point visual analogue scale (VAS) with endpoints of "no pain" (0) and "worst possible pain" (10) [16]. The mean point score in five different activities was calculated for pain in both legs perceived during resting, walking, walking upstairs and downstairs, and during the effort.

Statistical analysis

Data are mean and standard error (±SE). One-way analysis of variance (ANOVA) followed by Turkey *post hoc* comparisons was used to evaluate differences between the involved and uninvolved leg. A paired t-test was used to evaluate differences between pre- and post-HEP session. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

Before HEP, patients with knee OA showed a significant reduction ($p<0.05$) in the MVC force of the QF and HM muscles for the involved leg as compared with the uninvolved leg (Figure 1). After HEP, MVC force of the QF muscle increased ($p<0.05$) as compared with the pre-exercising level for the involved and uninvolved leg (Figure1a). MVC force of the QF muscle in patients with knee OA did not differ significantly ($p>0.05$) as compared with the uninvolved leg, whereas the HM muscle MVC force remained significantly lower ($p<0.05$) after HEP as compared with the uninvolved leg (Figure 1b).

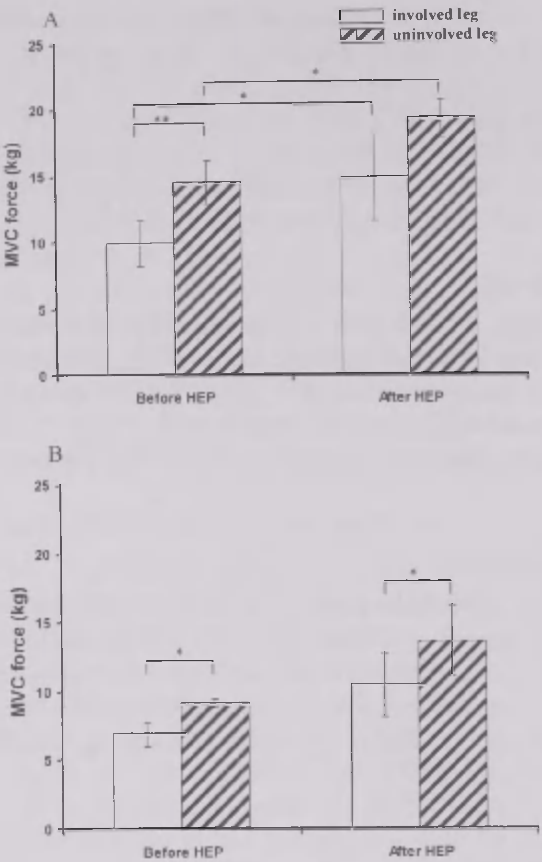

Figure 1. Mean (±SE) quadriceps femoris (QF) (A) and hamstring (HM) muscle groups (B) isometric maximal voluntary contraction (MVC) force in patients with knee OA before and two months after home exercise programme (HEP) (n=5), *p<0.05, **p<0.001.

Before HEP, patients with knee OA showed a significant reduction (p<0.05) in the aROM in flexion for the involved leg as compared with the uninvolved leg. (Figure 2). After HEP, aROM in flexion increased for the uninvolved leg (p<0.05) as compared with the pre-exercising level (Figure 2a.), whereas the involved leg aROM in flexion remained significantly lower (p<0.05) after HEP as compared with the uninvolved leg.

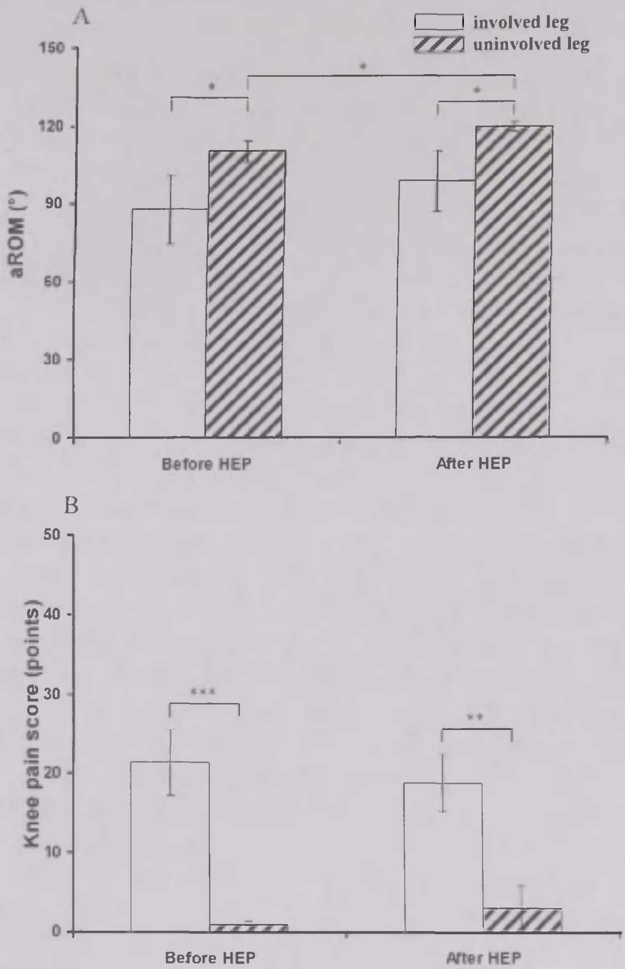

Figure 2. Mean (±SE) knee active range of motion (aROM) in flexion (A) and pain assessed by 10-point visual analogue scale (B) in patients with knee OA before and two months after home exercise programme (HEP) (n=5), *p<0.05, **p<0.01, ***p<0.001.

Knee pain score points for the involved leg were significantly (p<0.05) higher before HEP as compared with the uninvolved leg, and remained higher also after HEP (Figure 2b).

DISCUSSION

This study evaluated the effect of 2-month HEP on thigh muscle strength and aROM in patients with knee OA before TKA. The main finding of the study was the increase of MVC force in the QF muscle after 2-month HEP. Our results indicated that before HEP the MVC force of the QF and HM muscles for the involved leg was 32 and 25% lower respectively, as compared with the uninvolved leg. After 2-month HEP, MVC force of the QF and HM muscle for the involved leg increased 32 and 34% respectively as compared to the pre-HEP level, whereas there were no significant differences in QF muscle MVC force between the limbs. MVC force of HM muscles for the involved leg remained significantly lower two months after HEP as compared to the uninvolved leg. Patient No1 had 60 HEP sessions, and patient No 2 had 48 sessions – however, she performed exercises twice in the day, patient No 3 had 67 exercise sessions, patient No 4 had 67 sessions and patient No 5 had 88 sessions. One session lasted for 20–40 minutes. Swank et al. [24] compared patients with severe OA who underwent TKA. One group had usual care, the other group usual care and exercises that included resistance training using bands, flexibility, and step training at least three times per week for 4–8 weeks before TKA. They found that in the exercise group increased the leg strength (isokinetic peak torque for knee extensors and flexors), and the ability to perform functional tasks. They concluded that short-term (4–8 weeks) prerehabilitation was effective, easily transferred to a home environment, and they proposed that clinicians consider prerehabilitation before TKA. Brown et al. [3] in their case study measured isokinetic knee extension (QF) and flexion (hamstrings) with Biodex Isokinetic Dynamometer. A patient had prerehabilitation 4 weeks before TKA. After prerehabilitation, the patient demonstrated a 54% strength gain in her extension and a 34% gain of flexion strength of her involved leg. The prerehabilitation intervention emphasized three components: resistance training, flexibility, and step training; three session's treatment per week for four weeks. Rooks et al. [18] investigated the effect of a short pre-operative exercise intervention on the functional status, pain and muscle strength of patients before and after total knee joint arthroplasty. They used the 1-repetition maximum leg press test to determine lower-extremity strength. The patients' baseline leg strength was 97±37 kg, and the preoperative level was 116±37 kg. The patients performed water and land-based exercises three times weekly over a 6-week period prior to surgery. The result of the studies showed that after prerehabilitation in clinics, the involved leg muscles strength was increased. In our study, patients were instructed to perform the home exercise programme on the first meeting and after that they performed the exercises at home. Physiotherapist called on the phone to the patients every week and asked about the training results. Home exercise programme is a cheapest way to improve patients' condition before TKA. However, two patients canceled the surgery. The improvement of QF muscle isometric force-generation capacity after 2-month HEP can be explained by neural adaptation mechanisms. It has been suggested that exercise training for less than 2–3 months does not induce a significant hypertrophy in skeletal muscles [13]. Speed and Campbell [20] found that significant gains in strength in individuals with rheumatoid arthritis could occur due to neural adaptation without gains in muscle mass during the strengthening programme.

In our study, knee aROM in flexion before HEP for the involved leg was 21% lower as compared with the uninvolved leg. After HEP, the knee aROM in flexion for the involved leg increased 11%. Ipach et al. [8] reported that in patients before total knee arthroplasty mean knee aROM in flexion was 94 deg. Li et al. [11] found that pre-operative knee aROM in flexion was 95 deg. Stratford et al. [23] showed in their study that pROM in flexion was 109 deg. These data are similar to the results obtained in our study. The significant knee aROM increase before TKA is difficult expect in this group of patients, because OA induced changes in the knee joint and surrounding tissues. All tissues of the joint are involved, including bone, synovium, muscles, nerves and ligaments [6]. One limitation factor of this study was a small sample size (5 patients).

The pain measured by knee pain score before HEP was reduced 17% after HEP. Before HEP the uninvolved leg of the patients was pain free, whereas after HEP one patient reported pain in both legs. Knee pain was worse during stair walking, especially going down-stairs, and in the activities when patients carried extra weight in their hands (shopping). Rooks et al. [18] and Walls et al. [25] reported in their studies that the involved knee pain had a tendency to decrease.

In conclusion, this study demonstrated that 2-month HEP was effective for increasing QF muscle isometric strength in patients with OA. Isometric strength of HM muscles and knee aROM in flexion had a tendency to increase and knee pain for the involved leg had a tendency to decrease after HEP. It can be recommended to use home exercises (including mobility, strength and aerobic exercises) in the last stage of knee OA before TKA.

REFERENCES

1. Bade M. J., Kohrt W. M., Stevens-Lapsley J. F.(2010) Outcome before and after total knee arthroplasty compared to healthy adults. J. Orthop. Sports Phys. Ther. 40: 559–567
2. Bohannon R. W. (1986) Test-retest reliability of hand-held dynamometry during single session of strength assessment. Phys. Ther. 66: 206–209
3. Brown K., Swank A. M., Queasada P. M., Nyland J., Malkani A., Topp R. (2010) Prehabilitation versus usual care before total knee arthroplasty: a case report comparing outcomes with the same individual. Physiother. Theory Pract. 26: 399–407
4. Gogia P. P., Braatz J. H., Rose S. J., Norton B. J. (1987) Reliability and validity of goniometric measurements at the knee. Phys. Ther. 67: 192–195
5. Felson D. T., Naimark A., Anderson J., Kazis L., Casterlli W., Meenan R. F. (1987) The prevalence of knee osteoarthritis in the elderly. The Framingham Osteoarthritis Study. Arthritis Rheum. 30: 914–918
6. Goldring M. B., Goldring S. R. (2010) Articular cartilage and subchondral bone in the pathogenesis of osteoarthritis. Ann. NY Acad. Sci. 1192: 230–237
7. Ikeda S., Tsumura H., Torisu T. (2005) Age-related quadriceps-dominant muscle atrophy and incident radiographic knee osteoarthritis. J. Orthop. Sci. 10: 121–126
8. Ipach I., Mittag F., Lahrmann J., Kunze B., Kluba T. (2011) Arthrofibrosis after TKA – influence factors on the absolute and gain in flexion after manipulation under anaesthesia. BMC Musculoskelet. Disord. 12: 184
9. Jaggers J. R., Simpson C. D., Frost K. L., Quesada P. M., Topp R. V., Swank A. M., Nyland J. A. (2007) Prerehabilitation before knee arthroplasty increases postsurgical function: a case study. J. Strength Cond. Res. 21: 632–634
10. Knols R. H., Audemkampe G., de Bruin E. D., Uebelhart D., Aaronson N. K. (2009) Hand-held dynamometry in patients with haematological malignancies: measurement error in the clinical

assessment of knee extension strength. BMC Musculoskelet. Disord. 10: 31

11. Li B., Wen Y., Liu D., Tian L. (2011) The effect of knee postition on blood loss and range of motion following total knee arthroplasty. Knee Surg. Sports Traumatol. Arthrosc. (Epub ahead of print).
12. Mizner R. L., Petterson S. C., Snyder-Macer L. (2005) Quadriceps strength and the time course of functional recovery after total knee arthroplasty. Orthop. Sports Phys. Ther. 35: 424–436
13. Moritani T., de Vries H. A. (1979) Neural factors versus hypertrophy in the time course of muscle strength gain. Am. J. Phys. Med. 58: 115–130
14. Pertella R. J. (2000) Is exercise effective treatment for osteoarthritis of the knee? Br. J. Sports Med. 34: 326–331
15. Recommendations for the medical management of osteoarthristis of the hip and knee: 2000 update (2000) American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. 43: 1905–1915
16. Rejeski W. J., Ettinger W. H. Jr., Shumaker S., Heuser M. D., James P., Monu J., Burns R. (1995) The evaluation of pain in patients with knee osteoarthritis: the knee pain scale. J. Rheumatol. 22: 1124–1129
17. Rodgers J. A., Garvin K. L., Walker C. W., Morford D., Urban J., Bedard J. (1998) Preoperative physical therapy in primary total knee arthroplasty. J. Arthroplasty. 13: 414–412
18. Rooks D. S., Huang J., Bierbaum B. E., Bolus S. A., Rubano J., Connolly C. E., Alpert S., Iversen M. D., Katz J. N. (2006) Effects of preoperative exercise on measures of functional status in men and women undergoing total hip and knee arthroplasty. Arthritis. Rheum. 55: 700–708
19. Segal N. A., Glaus N. A., Torner J., Yang M., Felson D. T., Sharma L., Nevitt M., Lewis C. E. (2010) Quadriceps weakness predicts risk for knee joint space narrowing in women in the MOST cohort. Osteoarthritis Cartilage. 18: 769–775
20. Speed C. A., Campbell R. (2010) Mechanism of strength gain in handgrip exercise programme in rheumatoid arthritis. Rheumatol Int. (Epub ahead of print)
21. Stark T., Walker B., Philips JK., Fejer R., Beck R. (2011) Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review. PM R. 3: 472–479
22. Stefanic J. J.,Guermazi A., Zhu Y., Zumwalt A. C., Gross K. D., Clancy M., Lynch J. A., Segal N. A., Lewis C. E., Roemer F. W., Powers C. M., Feldson D. T. (2011) Quadriceps weakness, patella alta and, structural features of patellofemoral osteoarthritis: the multicenter osteoarthritis study. Arthritis Care Res. 63: 1391–1397

23. Stratford P. W., Kennedy D. M., Robarts S. F. (2010) Modelling knee range motion post arthroplasty: clinical applications. Physiother. Can. 62: 378–387
24. Swank A. M., Kachelman J. B., Bibeau W., Quesada P. M., Malkani A. Tropp R. V. (2011) Prehabilitation before total knee arthroplasty increases strength and function in older adults with severe osteoarthritis. J. Strength Cond. Res. 25: 318–325
25. Walls J. R., McHugh G., O'Gorman D. J., Moyna N. M., O'Byrne J. M. (2010) Effects of preoperative neuromuscular electrical stimulation on quadriceps strength and functional recovery in total knee arthroplasty. A pilot study. BMC Musculoskelet. Disord. 11: 119.

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ADOLESCENTS' PHYSICAL SELF-PERCEPTION AS RELATED TO MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY: A ONE-YEAR LONGITUDINAL STUDY

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ABSTRACT

The aim of the present longitudinal study was to follow the development of self-perceptions during early adolescence. The final samples for this study were 203 adolescents (105 girls, and 98 boys; mean age=15.2, SD=0.57). Adolescents completed Children's Physical Self-Perception Profile the four subdomain scales (sport competence, physical conditioning, strength, and body attractiveness), the general domain scale of physical self-worth, a global scale of self-worth. Longitudinal research indicates that the boys' perceptions of condition, sport, body, strength, physical self-worth and global self-worth were higher and they participated more in moderate to vigorous physical activity compared to girls. Sport and physical self-worth domains were the strongest predictors of moderate to vigorous physical activity for boys. Body and condition domains emerged as important predictors for girls. Our results demonstrate that physical self-perceptions are significant subdomains to physical activity and very stable at a moderate level during early adolescence.

Key words: gender differences, sport competence, physical conditioning, strength, body attractiveness, physical and global self-worth.

INTRODUCTION

Physical activity has been shown to assist children's psychological well-being and may assist their adherence to regular physical activity participation into adulthood [18]. There has been an increased interest in determining the influence of specific physical self-perceptions on health-related behavior in children and adolescents [7, 4, 14]. Whitehead [21] found that physical self-perceptions of body, sport competence, physical conditioning and general physical self-worth were all related to several field indicators of anaerobic, aerobic and muscular strength in seventh- and eighth-grade students. In general, a belief in one's ability greatest expectation of success, which in turn directs choice and persistence in behavior. Given the opportunity, those behaviors are sought that provide a sense of competence, and those avoided that carry a high probability of failure.

Studies among adolescents [17] have demonstrated an association between perceived athletic competence and involvement in sports. Research has shown that self-perceptions are most negative in early adolescence, girls have been shown to have lower self-esteem and a more dramatic decline through this period compared to boys [23]. Trzesniewski et al. [20], for example, found that interventions should target early adolescence because self-esteem stability at that developmental period is relatively low. In addition, Harter [11] indicated that physical self-perception was found to be the single most important predictor of general self-esteem across ages, especially in females. Great psychological and physiological changes take place in early adolescence, which probably affect the level of self-perceptions. Hagger et al. [8] investigated cross-cultural and sex differences in predicting moderate physical activity from self-perception. They found that several subdomains of physical self-perceptions (physical conditioning, sport competence, physical strength) were able to distinguish between high-active and low-active Russian and British children.

Reviewed several longitudinal studies the data showed self-esteem to increase in self-esteem with age [2]. Other longitudinal studies evaluating the stability of physical self-perceptions [1, 4, 15]. Raudsepp et al. [15] results indicated relatively high stability of the subdomains of physical self-perceptions at a group level, although instability of these self-perceptions at an individual level was observed. Therefore, the present longitudinal study adds a unique point of view to research on adolescents in Estonia.

The aim of this study was to examine the relationship between physical self-perceptions and moderate-to-vigorous physical activity in adolescents in the longitudinal study.

METHODS

Participants and procedures

The final sample for this study were 203 adolescents (105 girls, mean age=15.3, SD=0.61; and 98 boys, mean age=15.1, SD=0.53) from three schools from a town of 100,000 inhabitants located in southeast of Estonia. The present study included two data collections over the course of 12 months. The first time participants were in grade eighth. Two hundred and sixty-eight students took part in the first data collection (Time 1). An attrition rate of 24.3% at Time 2 was primarily due to students being absent from the schools on the day of the data collection. Using dummy-coding (stay vs. dropout) to test for possible differences among those students who took part in the second data collection (Time 2) and those who did not, the independent samples *t*-test was conducted on the mean scores of each study variable. No significant differences emerged on the variables, suggesting that attrition did not affect the results reported in this study.

Measures

All original inventories were translated into Estonian. After making some revisions in the translated versions, the items were then back translated into English by a bilingual expert. The factorial validity of the Children's Physical Self-Perception Profile (CY-PSPP) was tested with Confirmatory Factor Analysis using LISREL 8 [12]. The 36-item measurement model (i.e., six indicators per factor) provides an satisfactory fit to the translated CY-PSPP data ($\chi^2(579)=2416.18$, p=0.001, RMSEA=0.042; NNFI=0.92; CFI=0.94; IFI=0.93). CY-PSPP internal reliability using Cronbach's alpha coefficients for subdomains are presented in Table 1–2.

Perceived Competence

Perceived competence was assessed using the CY-PSPP [21]. The CY-PSPP consists of four subdomains that assess perceptions of sports competence (SPORT), physical condition (CONDITION), body attractiveness (BODY), and strength (STRENGTH). Three of the four subdomains (CONDITION, BODY, and STRENGTH) were based on modifications of Fox's original Physical Self-Perception Profile (PSPP) scales [6]. Harter's sport/athletic competence scale [9] was used for the SPORT scale since it was conceptually similar to Fox's original sport scale [6] and had been previously validated with children. A fifth subscale assessing global physical self-worth scale (PSW) [22] and sixth subscale general self-worth scale (GSW) [9] were included in the profile. Each scale contained six items in a structured alternative format [21]. The subjects first determined which of two options was most characteristic of him or her and then decided whether it was really true or only somewhat true of him or her. This format has been shown to reduce the tendency toward socially desirable responses [10]. The values ranged from 1 to 4, with the midpoint of the scale occurring at 2.5.

Physical activity

The physical activity assessment was accomplished using self-report of activity level on a series of 19 activity items [16], with three spaces for "other" activities. The scale was created to obtain an aggregate measure of the physical activity engaged in a weekly basis. Each level of the scale was assigned a weight as follows: ½ for "1–3 times a month," 2 for "1–2 times a week," 4 for "3–5 times a week," 6 for "Almost every day," and 7 for "Every day." Participants reported the level at witch they participated in each activity on a scale ranging from 1 "Never" to 7 "Every Day." Students were instructed to circle the number on the scale that corresponded to how often they participated in each activity for a least 20 min nonstop. For example, if a student never played volleyball they would circle "1" representing "Never" and if they played basketball twice a week they would circle "4" representing "1–2 times a week." These were used to estimate the number of times the subject engaged in each activity each week. These weights were then summed across the 19 (or more) activities to reach a total activity score. Evidence for the validity of the measure was found in the Stanford Adolescents Heart Health Program (SAHHP) [13] where self-reported regular exercisers were found to have resting heart rates lower than those of non-regular exercisers.

Statistical Analysis

The data analysis involves descriptive statistics, test-retest reliability, Coefficient α and multivariate analysis of relationships with MVPA. Dependent *t* test was performed to reveal differences in self-perception and MVPA measures. A longitudinal regression analysis was used to predict the variance in MVPA. Statistical significance was set at $p<0.05$.

RESULTS

Descriptive Statistics and Scale Reliabilities

Descriptive statistics, Coefficient α and Test-retest reliability for all variables are show in Tables 1 and 2. Physical activities were determined for MVPA scores across genders and CY-PSPP variables at the first measurement and at the second measurement with the some subjects were compared to assess changes that may have occurred.

Differences between first and at the second measurement

Dependent *t* test comparisons were conducted separately for boys and girls on the independent variables to assess changes that may have occurred. Results showed (Table 1) that for boys, statistically significant difference was significantly higher level of SPORT $t(1, 101)= 7.45$, $p<0.001$. Girls (Table 2) reported no differences between first and second measurement.

Table 1. Means, Standard Deviations, test-retest reliability and Coefficient α for the CY-PSPP items and physical activity for boys.

Age	*Alpha*	Boys (n=98)				test-retest
		14		15		
		mean	SD	mean	SD	
MVPA (points)		11.28	3.1	11.43	4.7	0.93
SPORT	0.758	2.71	0.68	3.06*	0.65	0.81
CONDITION	0.783	2.99	0.73	3.04	0.74	0.79
STRENGHT	0.818	2.69	0.62	2.72	0.67	0.87
BODY	0.723	2.74	0.76	2.84	0.78	0.92
PSW	0.713	2.79	0.74	2.91	0.62	0.85
GSW	0.765	2.93	0.65	3.07	0.65	0.93

MVPA – moderate to vigorous physical activity; PSW – physical self-worth; GSW – general self-worth. *p<0.05

Table 2. Means, Standard Deviations, test-retest reliability and Coefficient α for the CY-PSPP items and physical activity for girls.

Age	*Alpha*	Girls (n=105)				test-retest
		14		15		
		mean	SD	mean	SD	
MVPA (points)		10.35	8.1	10.56	6.7	0.87
SPORT	0.884	2.68	0.76	2.76	0.70	0.85
CONDITION	0.703	2.72	0.74	2.82	0.69	0.78
STRENGHT	0.722	2.46	0.69	2.54	0.60	0.87
BODY	0.663	2.58	0.73	2.51	0.66	0.92
PSW	0.673	2.91	0.75	2.97	0.64	0.95
GSW	0.725	2.89	0.63	2.93	0.75	0.86

MVPA – moderate to vigorous physical activity; PSW – physical self-worth; GSW – general self-worth.

Longitudinal regression model – Boys

Longitudinal regression analyses were conducted in order to determine the extent to which adolescent's exercise could be predicted from CY-PSPP subdomains gathered at the second measurement. Level of physical activity at the first measurement was statistically controlled by forcing it into each model first. Two variables entered the equation. SPORT emerged as a determinant of physical activity, $F(2, 99)=6.72$, $p<0.001$, accounted for 20% of the variance. PSW accounted for 12% of the variance, $F(2, 99)=5.85$, $p<0.001$. Together these variables accounted for 32% of the variance in the criterion.

Longitudinal regression model – Girls

Two variables entered the equation. BODY accounted for 16% of the variance, $F(2, 95)=3.85$, $p<0.05$. CONDITION accounted for 14% of the variance, $F(2, 95)=3.73$, $p<0.05$. Together these variables accounted for 30% of the variance in the criterion.

DISCUSSION

The aim of the longitudinal study was to examine the relationship between physical self-perceptions and MVPA in grades eighth to ninth. This analysis was conducted to provide a better understanding of children`s perceptions of motor competence.

Our results showed that boys reported statistically higher levels of SPORT. Being physically competent is clearly socially desirable for boys; therefore, they may have had a strong tendency to overrate themselves. Girls reported no differences between first and the second measurement. Girls are not rewarded for overstating perceptions: boasting is unfeminine. On the basis of the previous research in both academic and physical domains [1, 5, 9, 15, 20], it was hypothesized that accuracy in competence judgments would increase with the progression of the early adolescence.

An interesting finding was that the changes were minor among the boys and the girls. The reason for the stability and small changes in the mean levels of self-perceptions observed during adolescence may lie partly in the defense of the conscious self-concept against threatening or inconsistent information by means of various mechanisms [1, 4]. The results indicated, however, that SPORT and CONDITION domains were the strongest predictors of adolescent males and females MVPA involvement. SPORT is likely to be influential in adolescents' MVPA because of widespread involvement in organized sport both of schools and outside sport club organizations. Many of these most frequent physical activities also require a significant aerobic fitness of conditioning component. SPORT domain is likely to be influential in children's exercise participation because of widespread involvement in organized sport in both elementary school system and outside sport club organizations [3]. Using structural equation modeling techniques, physical self-perception models were able to predict 20–29% of the variance of the physical activity scores in both boys and girls. The variance explained by these models represents acceptable effect sizes when compared with values reported for psychosocial correlates of activity [19]. Furthermore, there was no evidence that sex moderated the relationship between physical self-perceptions and physical activity.

In this study, these adolescents had positive self-esteem during the follow-up period. The longitudinal analyses suggested that for boys' physical activity at the earlier age was strongly correlated with physical activity level during the eighth- and ninth-grade years ($r=0.31$). Important predictors of later physical activity for boys were CONDITION and PSW. For girls, previous level of physical activity was not correlated with physical activity at the second measurement ($r=0.15$). Other variable to enter the regression equation were BODY and CONDITION. Previous longitudinal research (mainly regarding self-esteem) has shown the correlations between two time-points to be high, thus indicating high stability during adolescence [1, 15] and also have concluded that self-esteem is likely to become more fixed or more consolidated with increasing age.

In summary, the major findings of this longitudinal study were that (a) CY-PSPP subdomains are important determinants of physical activity among early adolescents (b) boys' perceptions of CONDITION, SPORT, BODY, STRENGTH, PSW and GSW were higher and they participated more in MVPA compared to girls (c) longitudinal component of this study illustrates that the relative importance of determinants were very stable.

REFERENCES

1. Amorose A. (2001) Intraindividual variability of self-evaluations in the physical domain: Prevalence, consequences, and antecedents. J. Sport Exerc. Psychol. 23: 222–244
2. Butcher J. (1989) Adolescent girl's sex role development: Relationships between sport participation, self-esteem, and age at menarche. Sex Roles. 20: 575–593
3. Crocker P. R. E., Eklund R. C., Kowalski K. C. (2000). Children's physical activity and self-percpetion. J. Sport Sci. 18: 383–394
4. Crocker P. R. E., Sabiston C. M., Kowalski K. C., McDonough M. H., Kowalski N. (2006) Longitudinal assessment of the relationship between physical self-concept and health-related behavior and emotion in adolescent girls. J. Appl. Sport Psychol. 18: 185–200
5. Donnelan M. B., Trzesniewski K. H., Conger K. J., Conger R. D. (2007) A three-wave longitudinal study of self-evaluations during adulthood. J. Res. Pers. 41: 453–472
6. Fox K. R. (1990) The Physical Self-Perceptions Profile Manual. DeKalb, IL: Northern Illinois University, Office for Health Promotion
7. Hagger M. S., Asci H. F., Lindwall M. (2004) A cross-cultural evaluation of a multidimensional and hierarchical model of physical self-perceptions in three national samples. J. Appl. Soc. Psychol. 34: 1075–1107
8. Hagger M., Ashford B., Stambulova N. (1998). Russian and British children's physical self-perceptions and physical activity participation. Pediatr. Exerc. Sci. 10: 137–152

9. Harter S. (1982) The perceived competence scale for children. Child Dev. 53: 87–97
10. Harter S. (1985) Competence as a dimension of self-evaluation: Toward a comprehensive model of self-worth. In: The development of the self, R. Leahy (ed). New York: Academic Press. 55–121
11. Harter S. (1999) The construction of the self: A developmental perspective. New York: Guilford
12. Jöreskog K. G., Sörbom D. (1993) LISREL 8 user's reference guide. Chicago: Scientific Software International
13. Killen J. D., Telch M. J., Robinson T. N., Maccoby N., Taylor C. B., Farquhar J. W. (1998) Cardiovascular disease risk reduction in tenth grades: A multiple factor school-based approach. JAMA 260: 1728–1733
14. Lau P. W. C., Cheung M. W. L., Ransdell L. B. (2008) A structural equation model of the relationship between body perception and self-esteem: Global physical self- concept as themediator. Psychol. Sport Exerc. 9: 493–509
15. Raudsepp L., Kais K. Hannus A. (2004) Stability of physical self-perceptions during early adolescence. Pediatr. Exerc. Sci. 16: 138–146
16. Reynolds K. D., Killen J. D., Bryson S. W., Maron D. J., Taylor C. B., Maccoby N., Farquhar J. W. (1990) Psychosocial Predictors of Physical-Activity in Adolescents. Prev. Med. 19: 541–551
17. Roberts G. C., Kleiber D. A., Duda J. L. (1981) An analysis of motivation in children's sport: The role of perceived competence in participation. J. Sport. Exerc. Psychol. 3: 206–216
18. Shephard R. J. (1995) Physical activity, health, and well-being at different life stages. Res. Q. Exerc. Sport. 66: 298–302
19. Taylor W. C., Sallis J. F. (1997) Determinants of physical activity in children. In: Nutrition and fitness: Metabolic and behavioral aspects in health and disease, A. P. Simopolous, K. N. Pavlou (Eds). Basel, Switzerland: Karger. 82: 159–167
20. Trzesniewski K. H., Donnellan M. B., Robins R. W. (2003) Stability of self-esteem across the life-span. J. Pers. Soc. Psychol. 84: 205–220
21. Whitehead J. R. (1995) A study of children's physical self-perceptions using an adapted physical self-perception profile questionnaire. Pediatr. Exerc. Sci. 7: 132–151
22. Whitehead J. R., Corbin C. B. (1997) Self-esteem in children and youth: The role of sport and physical education. In The physical self: From motivation to well-being, K. R. Fox (Ed). Champaign, IL: Human Kinetics. 175–204

23. Zimmerman A., Copeland L. A., Shope J. T., Dielman T. E. (1997) A longitudinal study of self-esteem: Implications for adolescent development. J. Youth Adolesc. 26: 117–142

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3. Morgan W. P., Borg G. (1976) Perception of effort in the prescription of physical activity. In: humanistic and mental health aspects of sports, exercises, and recreation, T. Craig (ed). Chicago: Am. Med. Assoc. 256–259
4. Paoletti R. (1994) Future directions in drug treatment of atherosclerosis. 8th Int. Dresden Symp. On Lipoproteins an Atherosclerosis. Abstracts. Dresden, June 10–12, 1994, 22

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