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Beth P. Hands
University of Notre Dame Australia, bhands@nd.edu.au

Dawne Larkin
University of Western Australia, dlarkin@cyllene.uwa.edu.au

Helen Parker
University of Notre Dame Australia, hparker@nd.edu.au

Leon Straker
Curtin University of Technology, L.Straker@curtin.edu.au

Mark Perry
Curtin University of Technology, Mark.Perry@curtin.edu.au

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The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents

B. Hands[1], D. Larkin[2], H. Parker[1], L. Straker[3], M. Perry[3,4]

[1]School of Health Sciences, University of Notre Dame Australia, Fremantle, Australia, [2]University of Western Australia, Perth, WA, Australia, [3]Curtin University of Technology, Perth, WA, Australia, [4]Barts and the London School of Medicine and Dentistry, London, UK
Corresponding author: Beth Hands, School of Health Sciences, University of Notre Dame Australia, P.O. Box 1225, Fremantle, WA 6959, Australia. Tel: +(618) 9433 0206, Fax: +(618) 9433 210, E-mail: bhands@nd.edu.au

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Physical activity, physical fitness and motor competence are important health-related constructs. However, the relationship among them, particularly among children and adolescents, is still unclear. In this study, motor competence (measured by the McCarron Assessment of Neuromuscular Development), pedometer-determined physical activity and physical fitness (aerobic fitness, muscle strength, muscle endurance, flexibility and body composition) were examined in a cohort of 1585 adolescents (771 girls, 814 boys) of mean age 14.06 years. Significant gender differences were observed for all measures except motor competence. Apart from hip and shoulder flexibility, males outperformed females. For both males and females, motor competence was associated with all fitness measures, physical activity was associated only with aerobic fitness and aerobic fitness was associated with physical activity, motor competence, BMI and chest pass. Among males, aerobic fitness was also associated with all other fitness tests. The correlations were, in general, moderate to weak. The results challenge the current focus on physical activity rather than physical fitness as the preferred intervention.

The mounting evidence that sufficient physical activity is important for health in adolescents has sparked a number of studies and review papers seeking to identify the correlates of physical activity in this age group (Sallis et al., 2000; van der Horst et al., 2007). Two variables of interest are motor competence and physical fitness. However, while they are sometimes considered to be determinants of physical activity, they are also described as outcomes. High levels of physical fitness and motor competence are sometimes assumed to result from a high physical activity level (Castelli & Valley, 2007); however, the relationship is not this simple. While the first two are personal attributes, physical activity is a behavior and as such is determined by more psychosocial influences than the first two (Rowland, 2005). Further, the distinction between physical activity and physical fitness is often blurred, particularly in more recent years. The trend toward considering motor competence and fitness as outcomes of physical activity is due to several developments. Firstly, there is a heightened community awareness of the importance of physical activity to long-term health and well-being. Secondly, granting bodies are attributing a high priority to research focusing on physical activity, and finally more valid and objective measures of physical activity are becoming available. A recent bibliometric analysis of publications relating to physical activity highlighted this rapid change in focus (Bauman et al., 2007).

The privileging of physical activity has led to a shift in focus away from supporting the development of motor skills and physical fitness toward enhancing physical activity levels in children and adolescents. This is evidenced in Australia by the emphasis on physical activity opportunities rather than physical education in school curriculum. While the evidence strongly associates aerobic fitness with reduced cardiovascular risk in children and adolescents (Wedderkopp et al., 2003), the association is less clear with physical activity. The reciprocity of the physical activity–fitness–motor competence relationship is often overlooked. For example, without some level of competence in a range of motor skills along with the development of physical fitness, children are limited in the amount and range of physical activity they can undertake (Bouffard et al., 1996).

Identifying the relationship between these variables in adolescents is confounded by the plethora of methods used to measure each variable, and the influence of maturational and environment factors on this age group. Some generalizations can be drawn from the literature. In general, children with very poor coordination or motor skills are less active (Bouffard et al., 1996) and less fit (Hands & Larkin, 2006) than typically developing peers. On the other hand, children with high levels of motor competence are more physically active, more fit (Castelli & Valley, 2007) and spend less time being sedentary (Wrotniak et al., 2006).

As health-related fitness comprises a number of components (aerobic endurance, muscle strength, muscle endurance, flexibility, body composition), there is no clear and consistent association between all measures of fitness with physical activity. Where many studies have found physical activity strongly related to aerobic fitness (Raudsepp & Jurimae, 1998; Castelli & Valley, 2007), only weak relationships have been observed with other measures of health-related fitness (Pate et al., 1990; Sallis et al., 1993) including body fatness (Parsons et al., 1999).

The purpose of this study was to examine the interrelationships among physical activity, physical fitness and motor competence in a large sample of adolescents. Of additional interest will be the comparison of participants with high and low levels of each variable. Are the high active group also more fit and competent? Are the more competent group more fit and active? Are the high fit group also more active and competent? The participants are part of a longitudinal study that has been tracking a cohort of approximately 2800 since *in utero*. The data presented in this paper were gathered when the cohort was turning 14 years of age. Few studies have reported concurrent data for these three variables in such a large sample. The results of this study will aid in prioritizing focus and the appropriate targeting of interventions that seek to improve long-term health and well-being of adolescents.

Methods

Participants

Data from 1585 adolescents (771 girls, 814 boys) of mean (SD) age 14.1 (0.2) years were collected as part of their participation in the Western Australian Pregnancy Cohort "Raine" Study. This long-term project started as a pregnancy cohort in which 2979 women attending antenatal clinics at King Edward Memorial Hospital for Women were enrolled between 1989 and 1991. The children have been followed at birth, 1, 2, 3, 6, 8, 10, and now at 14 years of age. Inclusion criteria were gestational age between 16 and 20 weeks, sufficient proficiency in English to understand the implications of participation and an intention to remain in Western Australia so that follow-up through childhood would be possible. The protocol for the original study has been reported elsewhere (Newnham et al., 1993). Some attrition has occurred since the original study began, and the sample sizes for data for some variables differ as not all participants completed each assessment (Table 2).

The data for this present study were collected by a team of well-trained research officers over a 2.5-year time frame as the participants reached 14 years of age. This period reflects the time the mothers were recruited into the study. A physical assessment of the child including anthropometrics, motor competence and fitness was completed by one of the research teams at the Institute of Child Health Research. These measures were part of an extensive 2-day test battery.

Ethics

Parents of all participants provided written consent before participation. The study was approved by the Human Research Ethics Committee of Curtin University of Technology and Princess Margaret Hospital.

Measures

Physical activity

Physical activity was measured by Yamax Digiwalker SW200 pedometers worn on the right hip for at least 7 days. Objective monitoring of physical activity using pedometers has convergent (Tudor-Locke et al., 2002) and construct validity (Tudor-Locke et al., 2004) and the model used for the study has established reliability (Bassett et al., 1996). Daily step counts were recorded in an electronic ($n = 523$) or a paper diary ($n = 169$). The latter method was used where participants did not have access to a computer or did not wish to maintain an electronic log. Daily step counts below 1000 or $>$40 000 were discounted. A mean daily step count was determined for those participants recording feasible step counts for a minimum of 4 days, including at least one weekend day.

Physical fitness

A number of physical fitness components were evaluated using field tests from the Australian Fitness Education Award (ACHPER, 1996). These were upper body strength (chest pass), abdominal muscle endurance (curl-ups), hip flexibility (sit and reach), shoulder flexibility (shoulder stretch) and body composition (BMI).

Chest pass. Participants sat on the floor with their back, buttocks, shoulder and head flat against a wall, and their legs extended with the feet together. The examiner placed a hoop on top of participants' toes. Participants held a basketball with elbows touching the wall, and the ball touching their chest, and then used a two-handed chest to pass the ball through the top of the hoop. Distance was measured from the wall to the landing point and the best of two trials was recorded.

Curl-ups. Participants lay with their back and head on a mat, knees bent to 90° and feet flat on the floor. The arms were outstretched, grasping a pencil in the fists and resting on the thighs. The examiner placed a ruler over the peak of the knees to act as a target. No pressure was placed on participants' feet or knees. At a cadence of 20 curls per minute, set by a metronome, participants repeatedly curled up to touch their fingers on the ruler and returned to the starting position. The test ended after 60 curls or if the following occurred for two consecutive curls: curls were not in time with the beat, the grip on the pencil was released, one or both soles of the feet left the floor, one or both fists did not touch the ruler, the head did not make contact with the mat, or the arms/elbows were bent. The number of completed curls was counted.

Sit and reach. The Figure-Finder Flex tester was used to measure hip flexibility. To measure the right leg, with shoes removed, the participants sat on the floor and extended their

Table 1. Items from the McCarron Assessment of Neuromuscular Development (MAND)

Subscale	Test	Details
Fine	Beads in box	Number of beads moved from one box to an adjacent box in 30 s, repeated for both hands
	Beads on rod	Number of cylindrical beads placed on a metal rod held in non-dominant hand in 30 s, repeated with eyes open and then closed
	Finger tapping	Quality of movement and number of taps of index finger in 10 s, repeated on both hands
	Nut and bolt	Time taken to turn a large bolt, held in the dominant hand, fully onto a nut, repeated with a small bolt
	Rod slide	Moving a rod as slowly and smoothly as possible along a meter-long rod, repeated on both hands
Gross	Hand strength	Hand grip strength is measured with a hand dynamometer, repeated on both sides
	Finger/nose finger	The quality of accuracy and smoothness of movement of the index finger from nose to opposite hand's index finger is measured, repeated on both sides
	Standing long jump	Quality of movement and distance of a two-footed jump
	Heel toe walk	The quality of forward and backwards walking along a 3.05 m (10 ft) line.
	Standing one leg	With eyes open, the time the participant can balance on each leg, repeated with eyes closed

right leg so that their right foot was placed flat against a 30 cm high box placed against a wall. The opposite knee was bent, with the sole against the medial border of the extended knee. With palms prone and touching, participants reached as far forward as possible, holding for 2–3 s, with no jerkiness, unevenness of hands or bending of knees. The meter rule used for measurement projected from the box toward participants, with the 0 cm mark nearest to the participant and the 50 cm mark at the front edge of the box. The 23 cm mark was located above the toes. The best of two trials was recorded. This was then repeated on the left leg and finally with both feet placed against the box together.

Shoulder stretch. Participants reached their right hand over and behind their right shoulder, and their left hand behind their back toward the right shoulder, attempting to touch their hands together. The stretch was graded as "able" if participants could touch at least fingertips together. This was repeated on the opposite side.

Body composition. The height and weight of the participants was measured and BMI was calculated based on the formula weight (kg)/height $(m)^2$.

Cardiovascular endurance was measured on a bicycle ergometer using the PWC 170 (Physical Working Capacity 170). This test provides an estimate of VO_{2max} and is considered a suitable measure of aerobic fitness in this age group (Durant et al., 1983; Rowland et al., 1993). The heart rate (HR) at the three different loads was used to extrapolate the load required to lead to an HR of 170, using a linear regression. This was designated the PWC 170.

All of these tests have been validated previously in very similar forms, except the shoulder stretch, which has acceptable face validity (Rowland et al., 1993; Patterson et al., 1996; Shrier et al., 1998; Boreham et al., 2003; Tsimeas et al., 2005). The reliability of comparable forms of these tests is also good (McArdle et al., 1972; Patterson et al., 1996; Jones et al., 2002), although there are no reports on the reliability of the chest pass.

Motor competence

Motor competence was measured using the McCarron Assessment of Neuromuscular Development (MAND), which has good reliability and validity (McCarron, 1997). This test involves five fine motor and five gross motor tasks; brief details are provided in Table 1. Raw scores were awarded based on absolute qualitative and quantitative performance in each test, which were scaled to the participants' age according to conversion tables. These scores were then summed to yield a total overall scaled score. This was converted to the Neuromuscular Development Index (NDI) score, which has a normal distribution, with a mean of 100 and a standard deviation of 15 (McCarron, 1997).

Data analysis

All statistical analysis was performed using SPSS version 15. Gender differences were analyzed using independent *t*-tests for each of the scale variables, and chi-square tests for the categorical variables. The data for males and females were split for subsequent analyses.

Relationships between continuous variables were measured using a Pearson's correlation. Where data were missing, cases were excluded pairwise. As we were interested in comparing high and low performers in physical activity, motor competence and aerobic fitness, participants were grouped based on tertile cut points for each variable. The data for the middle third are not reported. The differences in outcomes for the high and low groups for motor competence, physical activity and aerobic fitness were compared using independent *t*-tests. Separate multiple regression models for males and females were developed for both physical activity and motor competence using the physical fitness components as predictors. Probability values of $P \leq 0.05$ were used to determine significance.

Results

The descriptive data for the total cohort, males and females are presented in Table 2. There were significant gender differences for all measures except motor competence. Males outperformed females on all items except hip and shoulder flexibility. As many participants did not participate in the pedometer study, independent *t*-tests were undertaken to compare the results for other fitness and motor competence data for those with and without pedometer data. There were no significant differences between the groups for any measure except for aerobic fitness (PWC 170) ($P = 0.006$). Those who did not participate in the pedometer study were more aerobically fit (113.1 W) than those who did (108.8 W).

Although significant, the correlations between many of the test items were moderate to weak for both males and females (Table 3). Physical activity

Table 2. Cohort characteristics of the whole sample, males and females

Variable	Total		Male mean (SD)		Female mean (SD)		Gender difference	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	t	P
NDI	1577	97.2 (17.4)	809	97.4 (18.1)	768	97.0 (16.6)	0.51	0.61
Steps per day	692	10747 (3920)	330	11 655 (4298)	362	9920 (3338)	5.89	< 0.001
PWC 170 score (W)	1503	111.2 (29.9)	778	124.4 (31.7)	725	97.1 (19.6)	20.19	< 0.001
Curl-ups (count)	1571	21.4 (17.4)	808	25.4 (18.8)	763	17.2 (14.7)	9.68	< 0.001
Basketball throw (m)	1585	5.3 (1.0)	816	5.7 (1.0)	769	4.8 (0.6)	22.04	< 0.001
S & R left leg (cm)	1581	24.1 (9.1)	813	20.4 (7.8)	768	28.1 (8.8)	− 18.09	< 0.001
S & R right leg (cm)	1581	24.8 (9.1)	813	21.1 (7.9)	769	28.9 (8.6)	− 18.47	< 0.001
S & R both legs (cm)	1580	23.4 (9.3)	813	19.8 (8.1)	768	27.2 (9.0)	− 17.24	< 0.001
Body composition (BMI)	1491	21.3 (4.1)	765	21.1 (4.1)	726	21.6 (4.2)	− 2.11	0.03
Variable	All participants (% able)		Males (% able)		Females (% able)		χ^2	P
Shoulder flexibility left	1585	88.6	817	84.8	768	92.7	24.45	< 0.001
Shoulder flexibility right	1586	95.1	817	93.1	769	97.3	14.58	< 0.001

NDI, Neuromuscular Developmental Index; PWC, Physical Working Capacity; PWC 170, estimated power output (W) at heart rate of 170 bpm; S & R, sit and reach; BMI, body mass index.

was weak but positively related to aerobic fitness (PWC 170) for both males ($r = 0.16$) and females ($r = 0.23$). Motor competence (NDI) was significantly correlated with all measures except for physical activity among both males and females. The largest correlations were with the fitness measures for upper body strength and flexibility. Aerobic fitness (PWC 170) significantly correlated with all measures among the males and all measures except for curl-ups and the flexibility tasks among the females. The largest correlation for both males and females was for upper body strength (males $r = 0.41$, females $r = 0.32$). Interestingly, the BMI did not significantly correlate with physical activity for either the males or the females. However, BMI was weakly and negatively correlated to motor competence (NDI) and muscle endurance (curl-ups), and positively correlated to aerobic fitness (PWC 170) and muscle strength (chest pass), for both males and females.

Standard multiple regression was performed between physical activity as the dependent variable and five physical fitness variables (BMI, curl-ups, sit and reach both legs, chest pass, PWC 170) as the independent variables for males and females separately (Table 4). This was repeated with motor competence (NDI) as the dependent variable (Table 5). Aerobic fitness (PWC 170) and body composition were significant predictors of physical activity for males, but only aerobic fitness was significant for the females. The variance explained was small for both males (4%) and females (6%). All fitness variables were significant predictors of motor competence for both males and females, and the variance explained was 27% for males and 20% for females.

High and low physical activity groups

The cohort was divided into thirds according to their level of physical activity, and the data were compared between the highest ($n = 230$, $M = 15\,053$ steps) and the lowest tertiles ($n = 230$, $M = 6898$ steps). As shown in Table 6, the low physical activity group had less aerobic fitness (PWC 170) and upper body strength (chest pass) but greater flexibility (sit and reach) than the high physical activity group. High and low active groups did not differ significantly for body composition (BMI), muscle endurance (curl-ups) or motor competence (NDI) ($P > 0.05$).

High and low motor competence groups

The cohort was divided into thirds based on their motor competence (NDI) scores. The highest tertile ($n = 502$) had a mean NDI of 117 and the lowest tertile ($n = 540$) had a mean NDI of 79. There were

Table 3. Simple correlations for each variable for males and females (bold)

	NDI	PA	PWC 170	Curl-ups	BMI	Chest Pass	S & R left	S & R right	S & R both
NDI		**–0.01**	**0.15****	**0.27****	**–0.13****	**0.33****	**0.23****	**0.22****	**0.22****
PA	–0.01		**.23****	**–0.02**	**0.01**	**0.04**	**0.03**	**0.05**	**0.07**
PWC 170	0.22**	0.16**		**0.06**	**0.27****	**0.32****	**0.06**	**0.04**	**0.04**
Curl-ups	0.37**	0.05	0.07*		**–0.27****	**0.18****	**0.22****	**0.23****	**0.22****
BMI	–0.08*	–0.08	0.18**	–0.26**		**0.17****	**–0.04**	**–0.04**	**–0.03**
Chest pass	0.43**	0.09	0.41**	0.31**	0.15**		**0.16****	**0.14****	**0.15****
S & R left	0.25**	–0.01	0.11**	0.26**	0.03	0.27**		**0.92****	**0.94****
S & R right	0.28**	0.01	0.10**	0.28**	0.02	0.28**	0.92**		**0.93****
S & R both	0.26**	–0.01	0.10**	0.25**	0.02	0.26**	0.92**	0.91**	

*$P<0.05$.
**$P<0.01$.
NDI, Neuromuscular Developmental Index; PWC, Physical Working Capacity; PWC 170, estimated power output (W) at heart rate of 170 bpm; S & R, sit and reach; BMI, body mass index; PA, physical activity/daily steps.

Table 4. Standard multiple regression of physical fitness variables on physical activity for males and females

Predictors	Males			Females		
	B	Exp (β)	sr^2	*B*	Exp (β)	sr^2
BMI	–126.01	–0.12*	0.01	–54.21	–0.07	<0.01
Curl-ups	0.55	<0.01	<0.01	–13.39	–0.06	<0.01
S & R both	–19.12	–0.04	<0.01	26.92	0.07	<0.01
Chest pass	181.72	0.04	<0.01	–184.22	–0.04	<0.01
PWC 170	22.94	0.17**	0.02	44.51	0.26**	0.06
R^2		0.04			0.06	
Adjusted R^2		0.03			0.05	
R		0.20			0.25	

*$P<0.05$.
**$P<0.01$.
PWC, Physical Working Capacity.

Table 5. Standard multiple regression of physical fitness variables on motor competence for males and females

Predictors	Males			Females		
	B	Exp (β)	sr^2	*B*	Exp (β)	sr^2
BMI	–0.41	–0.09**	<0.01	–0.60	–0.15**	0.02
Curl-ups	58.31	0.22**	0.04	0.17	0.15**	0.02
S & R both	0.27	0.12**	0.01	0.25	0.14**	0.02
Chest pass	5.48	0.31**	0.07	7.16	0.28**	0.07
PWC 170	0.05	0.08*	<0.01	0.07	0.08*	<0.01
R^2		0.27			0.20	
Adjusted R^2		0.27			0.19	
R		0.52			0.44	

*$P<0.05$.
**$P<0.01$.
PWC, Physical Working Capacity.

significant differences favoring the high competence group for all measures except for physical activity (Table 6) ($P>0.05$).

High and low aerobic fitness groups

The fitness component most strongly associated with cardiovascular risk is aerobic fitness and was therefore of most interest to this study. The cohort was divided into thirds based on their PWC 170 score. The high fit group ($n=501$) had a mean score of 145 and the low fit group ($n=501$) had a mean score of 83. As can be seen from Table 6, there were significant differences between high and low fit groups for all measures ($P<0.001$). Apart from the flexibility measures, all results favored the high fitness group.

Discussion

This study reported the relationships between physical activity, motor competence and five components of health-related fitness; aerobic fitness, muscle strength, muscle endurance, flexibility and body composition. The results confirmed significant gender differences for all variables except motor competence, with all, apart from flexibility, favoring the males (Table 2). For both males and females, motor competence was associated with all fitness measures, physical activity was associated only with aerobic fitness and aerobic fitness was associated with physical activity, motor competence, BMI and chest pass. Among males, aerobic fitness was also associated with all other fitness tests. The regression models supported these results. Of the physical fitness variables, only aerobic fitness was a significant predictor of physical activity; however, for motor competence all fitness variables, in particular, curl-ups and chest pass, were predictors.

Aerobic fitness and physical activity are two different constructs and, although significant, the relationship between them was weak ($r=0.23$ in females, $r=0.16$ in males) in this study, indicating a degree of independence. Similar results have been reported by others. For example, a weak to moderate association between physical activity and aerobic fitness was noted in younger children (Raudsepp & Jurimae, 1996), adolescents (Baquet et al., 2006) and adults (Talbot et al., 2000). For the other fitness

Table 6. Comparison of mean scores for high and low tertile groups for physical activity, motor competence and cardiovascular fitness

Test	Physical activity level				Motor competence				Aerobic fitness			
	High ($n = 230$)	Low ($n = 230$)	t	P	High ($n = 502$)	Low ($n = 540$)	t	P	High ($n = 501$)	Low ($n = 501$)	t	P
BMI	21.1	21.5	1.18	0.24	20.8	21.9	4.18	<0.001	22.0	20.5	5.66	<0.001
Curl-ups	22.3	20.2	1.32	0.19	27.9	14.9	12.56	<0.001	24.9	18.4	6.07	<0.001
Flexibility S & R left	23.1	25.2	2.54	0.01	26.2	21.9	7.85	<0.001	22.8	25.4	4.78	<0.001
S & R right	23.9	25.9	2.41	0.02	27.0	22.7	7.69	<0.001	23.4	26.2	5.02	<0.001
S & R both	22.6	24.4	2.11	0.04	25.6	21.2	7.94	<0.001	22.1	24.8	4.75	<0.001
Chest pass	5.1	5.5	3.95	<.001	5.7	4.9	13.05	<0.001	5.9	4.8	20.11	<0.001
Motor competence (NDI)	97.2	96.7	0.31	0.75					100.7	94.7	5.46	<0.001
Physical activity (steps per day)					10 736	10 773	0.10	0.92	12 085	9788	5.84	<0.001
Aerobic fitness (PWC 170)	119.2	101.7	6.13	<.001	118.1	106.6	6.06	<0.001				

BMI, body mass index; S & R, sit and reach; NDI, Neuromuscular Developmental Index; PWC, Physical Working Capacity..

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components, Malina (2001) did not find an association between physical activity and muscle strength, flexibility or body composition, even though one of the outcomes considered to be developed with physical activity is muscle strength. The correlations between fitness variables were also modest (except for the flexibility measures), indicating that each variable is measuring a relatively unique aspect of fitness. The inverse relationship between body composition (BMI) and aerobic fitness has also been observed in younger children aged between 7 and 12 years (Raudsepp & Jurimae, 1996; Castelli & Valley, 2007) and adolescents (Carnethon et al., 2005).

The greater flexibility measures recorded by the low active and low fit groups may reflect the type and variety of activities typically undertaken by more sedentary adolescents. Activities such as watching television and playing computer games do not develop muscle tone and may promote prolonged end of range postures that increase joint range. On the other hand, high-intensity, repetitive activities often required when participating in competitive, aerobic sports may reduce the range of motion around joints if regular stretching exercises are not undertaken (Wang et al., 2000). It is probable that few adolescents, unless engaged in elite sports, routinely undertake effective stretching exercises.

The positive correlation between BMI and chest pass is not surprising. In throwing events such as discus and shot put, successful competitors often have higher muscle mass that contributes to a higher BMI. On the other hand, a lower BMI was advantageous for performing the curl-ups, and was associated with higher motor competence for males and females.

The failure to detect a significant relationship between physical activity and motor competence could be attributed to the physical activity measure. In this study, physical activity was determined by a pedometer and therefore it was not possible to report the intensity, type or frequency of the activity. Pedometers primarily record locomotor movement that may or may not be the result of skillful activity. A relationship between aerobic fitness and physical activity may be observed if time spent in moderate and vigorous levels of physical activity is determined. The low competence group in this study were not less active but were less aerobically fit than their high competence counterparts. Consequently, it is possible that the participants with low competence may have recorded a similar number of steps per day to other members of the cohort, but at a reduced intensity.

Strong empirical evidence that physical activity rather than physical fitness or motor competence is of primary importance to health among children and adolescents is lacking (Rowland, 2005; Harris & Cale, 2006). While it is not possible to determine the directional nature of the relationships observed in this study, the results challenge the current emphasis by health interventions on boosting merely physical activity among children and adolescents. Given the regression models reported above, aerobic fitness should be considered to be of prime importance for several reasons. Firstly, aerobic fitness was related to both the attribute of motor competence and physical activity behavior. Secondly, valid and reliable objective measures of aerobic fitness for children and adolescents are available, whereas the measurement of physical activity in this age group is still problematic. While it is important to establish healthy levels of habitual physical activity among children, it is debatable whether this is of greater importance than focusing on fitness (Cale et al., 2007).

The term physical fitness is often erroneously used as a synonym for aerobic fitness rather than as an umbrella term to embrace all health-related fitness components. These results highlighted the importance of considering the broader concept of physical fitness. Participants who achieved high results for one fitness component did not necessarily rate well for another measure. There were only low to moderate correlations between most fitness components, particularly for males. To attain a healthy level of fitness, it appears necessary to be involved in a wide range of physical activities performed at an optimal level of intensity, which is yet to be ascertained.

Gender differences

The significant differences between males and females in this study are similar to other studies involving this age group. Regardless of the measure, age or setting, males from a very young age are consistently more physically active (Hands et al., 2004; Baquet et al., 2006) and aerobically fit (Michaud et al., 1999) than females. Gender differences are often reported in studies of motor competence, with males outperforming females in tasks involving power and strength, and females being the better performers on fine motor tasks, flexibility and balance tasks (Thomas & French, 1985). The motor competence assessment used in this study (McCarron, 1997) includes tasks that are gender neutral, or where gender differences are apparent, such as the jump task, separate norms are provided. This could account for the similar results between males and females for motor competence.

Strengths and limitations

The data for this paper are cross-sectional, and therefore it is not possible to determine whether the observed relationships are causal; however, a strength of the study is the potential to track these constructs as the cohort matures. At present, these measures are being repeated as the participants turn 17 years of age.

Several limitations should be noted. The sample described was not drawn randomly but were enrolled into the study *in utero*. Although the attrition rate is relatively small, participation numbers vary for most measures. This is evident with the low response rate for the pedometer study. The participants found the 7-day study challenging and time consuming and, consequently, complete records for at least 4 days were not always provided.

While motor competence and fitness measures for adolescents are well established, the valid and reliable measurement of physical activity remains a challenge. To date, many diverse conclusions are made by scientists due to variations in measures, protocols, populations and settings. Results from studies involving children around puberty have the potential to be confounded by growth factors. Changes in body dimensions can moderate performance while learning to adjust. While most participants in this study were probably post-puberty, some may still have been experiencing growth spurts. This may have contributed to a greater variability of outcomes within the cohort and consequently lower correlations between measures. A further consideration is the age-related decline in physical activity commonly associated with the onset of puberty (Sallis, 2000). Finally, while the pedometer is an appropriate tool for population-based studies, it does not record the intensity, type and duration of activity. Further, pedometers do not accurately register some common activities such as cycling or skateboarding, and cannot be worn while swimming.

Perspectives

Physical activity, motor competence and physical fitness are all related to better health outcomes in children and adults. The current focus on physical activity with children appears inadequate as the three constructs are only partly related. Given the difficulty to objectively measure physical activity in children (Welk et al., 2000), it may be more useful to measure and monitor aerobic fitness. Such measures are more objective and less prone to misclassification. Further, more opportunities need to be provided for children and adolescents to develop other fitness components such as muscle strength and flexibility. At present, researchers and health professionals are still debating what should be the recommended threshold for sufficient physical activity to achieve health benefits in children, but also the role of fitness testing (Cale et al., 2007). Recent changes to the recommendations for adults have clarified the important contributions of aerobic fitness, muscle strength and endurance to health (Haskell et al., 2007). Interventions that only support physical activity may not be maximizing the opportunities to improve health outcomes for children and adolescents. As activity levels tend to track through to adulthood (Malina, 1996), the opportunity to improve adult health outcomes may also be compromised. Clearly, further research is warranted.

Key words: aerobic fitness, muscle strength, muscle endurance, BMI, flexibility.

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