Original Research

Physiological Characteristics of Youth Synchronized Skaters

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ABSTRACT

International Journal of Exercise Science 9(3): 270-282, 2016. Figure skating is a lifelong sport with participation rates increasing for skaters of all ages. Development within the five disciplines of figure skating (individual skating, synchronized skating, pairs skating, ice dancing, and theater on ice) has led to increased physical demands placed on skaters' bodies. As a result, focus on sport performance testing, training, and injury prevention specific to figure skating is increasing. The purpose of this study was to use field tests to describe the physical characteristics of synchronized skaters and to determine the relationships between these physiological characteristics and skating abilities. Anthropometric data were collected and field tests (sit-and-reach, vertical jump, hexagon, one-min sit-ups, one-min modified pushups, timed wall sit, and one-mile walk/run) were performed during off-ice fitness classes as part of synchronized skating camps. Participants were divided into Advanced (ADV) (n = 20; "intermediate and above") and Beginner (BEG) (n = 21; "juvenile and below") groups determined by their *Moves in the Field* (*MITF*) test levels. Significant differences were found between ADV and BEG groups for age, body weight, height, BMI, sit-and-reach (SR), and vertical jump height (VJ). Results from univariate statistics and paired *t-tests* ($p \leq 0.05$) indicated that the anthropometric variables of age, body weight, height, and BMI were greater for the ADV group as compared to the BEG group and were consistent with their greater physical development. SR (flexibility) and VJ (explosive power) were greater for the ADV group; as such, these may be athletic components to target as skating ability develops. Future research to identify fitness norms for skaters by level of skating ability (*MITF*) may assist synchronized skating coaches in the design of off-ice training programs to improve on-ice skating performance.

KEY WORDS: Off-ice training, children, physical fitness testing

INTRODUCTION

The sport of figure skating consists of five competitive disciplines: Singles, Pairs, Ice Dance, Synchronized Skating, and Theater on Ice (30). All skaters in these disciplines must perform variations of footwork-step sequences, spiral sequences, and innovative choreography relative to the demand of the discipline. In order to progress through and perform at the different levels of competitiveness in each discipline defined by United States Figure Skating (USFS), the figure skating governing association in the United States (U.S.); a skater must complete a series of standardized performance tests

(28). The standardized tests within the USFS Test Track assess competence in skating skills and elements, and promote consistency in the rating of skating ability across competitive disciplines. A panel of three trained judges evaluates the results of the tests using a point system to pass or fail a skater at a test level. Having a higher test level and a greater variety of test disciplines indicates a greater skating ability and competence.

Participation within the discipline of synchronized skating has increased due to the development within and popularity of the sport. Synchronized skating is a lifelong sport with participants ranging in age from youth (5-10 yrs) and adolescents (11-20 yrs) to adults (>21 yrs) (7, 28). Synchronized skating is unique and includes elements from each of the disciplines to be performed by 8-16 skaters simultaneously (jumps and spins from singles; spiral sequences, and spins from pairs; variations of dance lifts and spins from ice dance; intricate footwork-step sequences from all disciplines). These elements are performed in formations, individual as well as connected, consisting of varied blocks, circles, wheels, lines, or intersections. An individual skater is placed on a synchronized skating team level based on his or her *Moves in the Field* (*MITF)* test levels and disciplines of the USFS Test Track (28).

Skill development and advanced performance standards within all disciplines of figure skating have led to increased physical demands being placed on skaters' bodies (7, 13). As a result, focus on sport performance testing, training, and injury prevention specific to synchronized skating has increased. Developing greater athletic ability through training and an improved level of physical fitness could aid in the acquisition of skating skills and injury prevention (13, 25, 31). Incorporating training recommendations early in a skater's career may allow the skater to train at his or her highest capability and develop skating skills, as well as introduce the importance of overall physical fitness to the skater. Figure skaters are often required to demonstrate proper form and posture, creative grace and style, and correct technique all while executing elements that require high levels of athleticism (13, 25, 26).

The USFS was first officially recognized by as a discipline in 1956. Synchronized skating (then known as precision skating) had been developed from chorus line skating and was used as a form of entertainment during hockey games (28). This discipline was not nearly as physically demanding as it is currently. Since 1984, when precision skating became nationally competitive, the sport has continued to develop in regards to both the number of participants and amount of athleticism required. For example, overhead lifts were added in 2002. Now, a highly competitive international sport with the first World Championships held in 2000 under the auspices of the International Skating Union, the difficulty and athleticism required of synchronized skaters demonstrated by the ability to spin, lift teammates, and maintain greater endurance has increased (28).

In 2015-2016, there were more than 581 teams nationwide with approximately 5000 skaters participating in synchronized skating championships at the sectional level

(29). In 2008, the number of teams was 500, with 40% of the teams at the beginner to juvenile levels, which are comprised of skaters who are ages 13 years and younger. The next largest grouping of teams in 2008 was made up of teams with skaters between the ages 13-17 years and represented 35% of the teams (28). Educating synchronized skating teams from the grass roots levels to elite levels about appropriate training programs would be an opportunity to reach large numbers of USFS members and continue to advance the depth of competitiveness of U.S. Synchronized Skating.

There is a lack of published data regarding the physical characteristics, anthropometric traits, and fitness performances of synchronized skating athletes. Fitness testing results are important components for the design of an appropriate program to meet the needs of an individual skater. Fitness tests can be utilized to assess current fitness levels for strengths and weaknesses, identify special needs for individualized programming, evaluate progress, and motivate the athlete who participates in synchronized skating (19). Fitness performance data could also be beneficial to establish baseline measures and identify realistic goals for the improvement of each component of a skater's physical fitness.

Therefore, the purposes of this study were: a) to assess and summarize physical characteristics, consisting of anthropometric traits and fitness performance variables of youth synchronized skaters; b) to identify differences between beginning and advanced synchronized skaters in physical characteristics related to skating ability; c) to study potential relationships between physical characteristics and skating ability when categorized into *MITF* levels (30).

METHODS

Participants

Apparently healthy, physically active synchronized skaters ranging from 11-18 years of age and classified by on-ice skill levels were recruited for the study. Forty-four (41 females; 3 males) skaters from various geographical locations in the United States and Canada attended a two week synchronized skating camp. For the final statistical analysis, the males were excluded due to the small sample size (n = 3).

During an orientation session, the procedures of the study were verbally explained to each participant, and then written explanations were distributed. If the synchronized skater and parent/guardian agreed to participation, the parent or guardian and the synchronized skater signed the informed consent/assent documents. In addition, each skater completed a Medical and Exercise/Training History Questionnaire, a Responsibilities of User and Waiver Form, and a Medical Authorization Form. The investigation was approved by the Bowling Green State University Human Subjects Review Board.

Individual skill levels of the participants ranged from no *MITF* scores completed to Junior MITF (see Table 1). *MITF* levels are established by the United States Figure Skating Association (32) and comparable levels are established by Skate Canada. The

Pre-preliminary *MITF* Test (lowest level) would include forward perimeter stroking, basic (four) consecutive edges, forward left and right foot spirals, and Waltz eight. These moves would be evaluated for power and extension and edge quality (32). In contrast, at one of the advanced levels, Junior *MITF* Test, the six moves would include forward and backward outside rockers, forward and backward inside rockers, power pulls, Choctaw sequence, backward loop pattern, and straight line step sequence. These moves would be evaluated for power, extension, edge quality, quickness, and continuous flow (32).

Protocol

The sit-and-reach test assesses flexibility of the hamstrings and lower back (16). Each participant was instructed to sit on the floor with her legs fully extended to the front with the soles of her feet touching the self-constructed sit-and-reach box. Each participant was instructed to reach forward as far as possible, slowly allowing the head and shoulders to move forward while the fingertips moved along the yardstick. The greatest score of the three trials performed in succession with 15-20 sec between each trial was used for data analysis (16, 23).

The vertical jump is “sport specific” for any activity that includes jumping or explosive lower body movements and is an appropriate power test for figure skating (8, 16). The vertical jump was completed having each participant stand against a wall and reach as high as possible while flat footed with the dominant arm. A piece of tape was positioned at the top of the finger tip. Each participant performed a two legged jump, jumping as high as possible using a downward countermovement with both arms swinging prior to the jump to maximum jump height (8). At the apex of the jump the participant marked the wall with a piece of tape at the finger tip reaching as high as possible utilizing both arms equally to full extension. The greatest score of three trials was recorded with 5 min of rest occuring between the trials (6, 16, 23). The validity and reliability coefficients for the vertical jump are 0.78 and 0.93, respectively (23).

The hexagon test is used to assess agility, the ability to stop and start, quickness of foot speed and legs, change of direction, and whole body coordination (5). The movement performed in the hexagon test is an off-ice simulation of fast, full body coordinated movement in all directions. Each participant performed double-leg hops from the marked center of the hexagon to the outside of each of six sides returning to the marked center in a continuous clockwise sequence. One trial consisted of three revolutions around the hexagon. The self-constructed hexagon sides were each 24 inches in width and angled at 120 degrees. The participant faced the same direction as she completed the full revolutions. After three trials were performed with 5 min of rest occuring between the trials, the best score in seconds was recorded from the stopwatch (6, 8).

The one-minute sit-up test is a muscular endurance test of the abdominal muscles and hip flexors (core strength) (5). Sit-ups were completed with each participant intially supine on the floor with knees flexed, feet flat on the floor held down by a partner, lower and upper back flat on the floor, and hands interlocked behind the neck (5, 23). Each participant completed as many sit-ups as possible in one minute while maintaining proper form for one trial of the test. Proper form consisted of touching the thighs with the elbows as the participant sat up, and returning the upper back to the floor as the trunk was lowered. During the sit-up the buttocks remained flat against the floor (5). The validity of this test has been reported to be logical validity with the reliability coefficient of 0.68 - 0.94 (23).

The one-minute push-up test is a muscular endurance test of the arms, upper back, and chest muscles (5). Each participant started face down, flat on the floor, with the hands placed under the shoulders. A modified push-up with knees on the ground to support the body instead of the feet was utilized. Each participant performed as many push-ups as possible in one minute for one trial of the test while maintaining proper form (a flat trunk without the stomach/hips sagging or trunk flexion, lowering the nose all the way to the floor on descent, and extending the arms completely on ascent). If the arms did not make at least a 90° angle on the descent, the push-up was not counted. The validity of scores for the one-minute push-up is reported as logical validity, and the reliability coefficient is reported as 0.83-0.97 (23).

The timed wall sit also known as the phantom chair or isometric leg squat is intended to measure static leg endurance (24). Each participant began with her back against the wall and walked her feet out in front until the knees were bent to a 90° angle with thighs perpendicular to the wall. Once in postion, the feet remained flat on the floor, the lower and upper back stayed flat on the wall, and the participant's arms hung loosely at her sides for the duration of the test. One trial was performed; the score for this test was the length of time the participant maintained the proper position (23).

The one-mile walk/run test was used to assess cardiorespiratory endurance (19, 24). Running was strongly encouraged, but because youth were tested, anyone who was unable to run the entire distance was encouraged to walk as fast as possible to complete the distance. All participants lined up together and began the run when "start" was called. As each subject crossed the finish line times from a stopwatch were recorded. One trial was completed.

There were three days of testing. On the first day of testing, height was measured using a portable stadiometer (Country Technology, Inc., Gays Mills, Wisconsin), body weight was measured using an electronic scale (*Soehnle Digital S* scale, Nassau/Lahn, Germany), and waist and hip circumferences were measured using a Gulick tape (FitnessMart® a division of Country Technology, Inc., Gays Mills, Wisconsin). Body Mass Index was calculated as body weight (kg) per height times height (meters).

Prior to each test session, the skaters participated in a 10-min warm-up consisting of light jogging, and dynamic and static stretching. The first day of testing included completion of the sit-and-reach, vertical jump, and hexagon agility tests. On day two, the one minute modified push up test, the one-minute sit up test and timed wall sit test were administered. On day three, the participants performed the one-mile walk/run test.

Synchronized skaters participated in daily off-ice fitness classes during summer synchronized skating camps. Fitness testing was included as part of the overall lesson plan for a full week of fitness classes. The field tests that were to be completed for the study were practiced two times before test administration (with the exception of the one-mile walk/run test). This practice time allowed the skaters time to learn and familiarize themselves with the tests and expectations. The actual testing was performed during the fitness class times the last three full days of camp. All of the fitness tests were performed in the designated fitness room inside an ice arena. The one-mile walk/run test was performed outside on a 400-meter speed skating oval without ice.

Table 1. Beginner (BEG) and advanced (ADV) levels (N = 41).

Code/Level	*n*	USFS *Moves in the Field* (*MITF*)	Canadian Skating Skills (Equivalent levels)
0	1	No Test	
1	2	Pre-Preliminary	
2	13	Preliminary	Preliminary
3	3	Pre-Juvenile	
4	2	Juvenile	Jr. Bronze
BEG	*n* = 21		
5	9	Intermediate	Sr. Bronze
6	7	Novice	Jr. Silver
7	4	Junior	Sr. Silver
8	0	Senior	Gold
ADV	*n* = 20		

Note. USFS – United States Figure Skating (30)

Skating ability was predetermined according to the on-ice proficiency test, U.S. Figure Skating *MITF*. Each skater had passed the appropriate level test before camp. An equivalent test called *Skating Skills* is used by Skate Canada. Skaters were divided into Beginner (n = 21) and Advanced (n = 20) groups (see Table 1) based on *MITF*. The second categorization consisted of coding the MITF tests into nine levels corresponding with each *MITF* test level and a No Test category (Levels 0-8, *MITF* skill levels) (see Table 1).

Statistical Analysis

Descriptive and other statistics (means and standard deviations) were computed for all variables using SPSS 18 (Armonk, NY). To assess differences between skating ability between the groups, beginner (BEG) and advanced (ADV), paired *t-tests* were calculated for all dependent variables. Alpha was set at $p \le 0.05$. Zero-order Pearson correlation coefficients were computed to determine if there were any relationships between anthropometric and physiological performance variables and skating abilities (coded into nine levels according to *MITF* skill levels, see Table 1). A first-order partial correlation analysis was also calculated to determine if any of the relationships between fitness performance variables and skating ability were affected by the anthropometric variables (representative of physical development).

RESULTS

The anthropometric and fitness variables for all participants are shown in Table 2. Significant differences between the means of the BEG and ADV groups were found for age, body weight, height, and BMI ($p \le 0.05$) (see Table 3). These means were significantly greater in the ADV group supporting greater age and developmental progress for this group. There was no difference between the groups for Waist-to-Hip Ratio.

Table 2. Anthropometric and fitness data for beginner and advanced groups (N = 41).

Variable	Beginners (*n* = 21)	Advanced (*n* = 20)	*p* value	Total (*N* = 41)
Anthropometric				
Age (years)	12.6±0.97	15.0±1.3	0.000*	13.8±1.6
Body Weight (kg)	51.2±10.3	62.5±12.4	0.003*	56.7±12.6
Height (cm)	155.1±8.7	163.8±6.5	0.001*	159.0±9.0
BMI (kg/m²)	16.6±3.0	24.4±4.4	0.000*	20.4±5.4
W/H Ratio	0.75±0.04	0.76±0.03	0.580	0.75±0.04
Fitness Performance				
Sit and reach (cm)	37.7±8.3	44.1±5.8	0.007*	40.8±7.8
Vertical jump (in)	11.0±2.9	15.2±1.8	0.000*	13.0±3.1
Hexagon jump (sec)	14.7±1.3	14.4±1.2	0.487	14.6±1.2
One-min sit-up	31±7	35±7	0.061	33±7
One-min modified push-up	25.0±11.0	28.0±9.0	0.348	26.5±10.1
Timed wall sit (min)	2:32±2:31	1:38±0:54	0.139	2:06±1:56
One-mile walk/run (min)	9:28±1:24	8:24±1:59	0.053	8:57±1:45

*$p \leq 0.05$, ADV vs. BEG *t-test*

Differences between the means of the fitness performance variables of the ADV and BEG groups were significant for sit-and-reach and vertical jump variables (see Table 2). The means for the hexagon jump, one-minute push up, wall sit, one-minute sit up, one-mile walk run, were not significantly different between the groups.

The results of the zero-order correlation demonstrated significant relationships between age, body weight, height, BMI, sit-and-reach score, vertical jump height, number of sit-ups, and one-mile walk/run time variables with skating ability when coded as *MITF* levels (see Table 3). The significant dependent variables for the correlation analysis are similar to the variables that were significantly different between the ADV and BEG groups shown by the *t-test* analyses (see Table 2). All of the variables that had a significant difference between skating ability (coded as *MITF* levels; age, body weight, height, BMI, sit and reach score, and vertical jump height) were also found to be significantly correlated to skating ability in the zero-order correlations (see Table 3). When developmental characteristics were controlled, there were significant partial correlations most often for sit-and-reach scores, vertical jump height, number of sit-ups in one minute, and one-mile walk/run test with *MITF* levels (see Table 4).

Table 3. Relationship between anthropometric and fitness measures, and skating ability (MITF levels).

Variable	*r* (0-Order)	*p* value
Anthropometric		
Age (yr)	0.688	0.000*
Body Weight (kg)	0.389	0.012*
Height (cm)	0.433	0.005*
BMI	0.662	0.000*
W/H Ratio	0.224	0.159
Fitness Performance		
Sit and Reach (cm)	0.360	0.021*
Vertical jump (in)	0.738	0.000*
Hexagon Jump (sec)	-0.061	0.706
One-min Sit-Ups	0.377	0.015*
One-min Modified Push-Ups	0.290	0.066
Timed Wall-Sit (sec)	-0.055	0.735
One-Mile Walk/Run (sec)	-0.366	0.19*

*$p \leq 0.05$

DISCUSSION

There is a lack of published data regarding the physical characteristics, anthropometric traits, and fitness performances of synchronized skating athletes. One aim of this study was to collect baseline measurements of physiological characteristics (anthropometric and fitness measures) of synchronized skaters to develop a better understanding of the athletic ability and training needs required for the sport at developmental levels and ages. A second aim of the study was to determine the relationship between these physiological characteristics and skating ability. Skating ability was measured in two ways: (a) grouping skaters into beginning skill (BEG) and advanced (ADV) skill groups; and (b) using an ordinal scale of skating ability.

Table 4. Correlations between fitness tests results and MITF levels; zero-order and controlling for physical development (*1st-Order*).

		Controlling for				
Fitness Variable	0-Order	Age	Wt	Height	BMI	WHR
Sit and Reach (cm)	*r*=.360* *p*=.021	.228 .156	.315* .048	.303 .057	.211 .191	.378* .016
Vertical Jump (in)	*r*=.738** *p*=.000	.608* .000	.697* .000	.674* .000	.627* .000	.769* .000
Hexagon Jump (sec)	*r*=-.061 *p*=.706	-.084 .608	-.051 .755	.020 .903	-.024 .883	-.111 .494
One-min Sit-Ups	*r*=.377* *p*=.015	.322* .043	.372 .018	.300 .060	.404* .010	.383 .051
One-min Push-Ups	*r*=.290 *p*=.066	.281 .078	.272 .090	.286 .074	.309 .052	.296 .064
Timed Wall Sit (sec)	*r*=-.055 *p*=.735	.156 .335	.059 .719	.086 .599	.188 .244	-.013 .526
One-Mile Walk/Run (sec)	*r*=-.366* *p*=.019	-.526* .000	-.516* .001	-.351* .027	-.575* .000	-.416* .008

*$p \leq 0.05$; **$p \leq 0.01$

All anthropometric measures were greater for the ADV group with the exception of the waist-to-hip ratio (see Table 2). The ADV group's mean age was approximately two and a half years greater than the BEG group. The significant difference between chronological ages of the groups suggest physiological and developmental differences. The height and weight measurements have also been included in this study to determine if these synchronized skaters match the generalized impression that figure skaters are shorter and lighter. Leanness and linearity are characteristics often associated with figure skaters and are typically determined through general observation and in reported data (15, 18, 20, 21). The importance of these physical characteristics has been emphasized in various figure skating publications (15, 18, 20, 21). Smaller athletes tend to have higher strength to body weight ratios or greater relative strength. Leaner bodies with greater muscle mass relative to overall body weight, often thought to be an aesthetic quality in figure skating, can aid the skater in propelling across the ice and into the air for a jump (15, 18, 20, 21).

The average weight and height for all 41 subjects placed the total group mean in the 76th and 50th percentiles, respectively, according to the *CDC Growth Charts* for children and youth of comparable ages (11). When the total sample was divided into the skating ability groups, the BEG group mean weight remained at the 75th percentile, but was at the 37th percentile for height (25). The ADV group mean body weight was greater at the 80th percentile, and at the 60th percentile for mean group height (11). When reviewing the mean BMI the total sample (N = 41) was at the 63rd percentile, while the BEG group was much lower at the 20th percentile, and the ADV group much greater at the 85th percentile (11) possibly suggesting that the ADV group was approaching overweight. While the BMI might have been higher in some skaters because they were athletes with more muscle mass, qualitative observation of the synchronized skaters in this study indicated that the skaters did not necessarily fit the profile of figure skaters who are generally shorter, lighter, and leaner when compared to similar age and gender matched sedentary counterparts (10, 15, 20, 21).

Much of the published data on anthropometric measures of any discipline within figure skating has been reported for slightly older skaters with ages beginning at 14 years ranging to the mid-twenties (10, 15, 20, 21). The mean age of the subjects in this study was 14 years with the BEG and ADV groups' means of 12.6 and 15.0 years, respectively. This difference suggests the need for more data collection for synchronized skaters at younger ages, before as well as after puberty. The need for such data becomes increasingly important when noted that the average age for North American girls to reach puberty and begin the menstrual process is 12.3 – 12.8 years of age and it has been observed that athletic females typically experience the menstrual process one to two years later than their sedentary counterparts (2). Hormonal changes may increase growth rates for height, muscle mass, body fat, and bone. The assessment of age of menarche was beyond the scope of the present study, but could account for variability in the scores for height, weight, and BMI. Future studies may measure and investigate how age of menarche affects skaters and their abilities. Previous studies have shown that there is a greater possibility for injury to occur in physically maturing athletes due to rapid growth spurts, loss of coordination, muscle and connective tissue growth imbalances and joint inflexibility (4, 12).

Most of the differences found between the BEG and ADV groups for the fitness performance variables were in the expected direction, and similar to the differences between groups found in the anthropometric measures. Based on the results of this study, it appears that physical development is related to the ability to achieve greater skating skills. Separating beginner and advanced skaters by skill level for on- or off-ice training may be advantageous because physical differences tend to correspond with skill level (as reported in this study). Grouping skaters may aid in delivering a sport-specific training session and realistic expectations for skill acquisition to the skaters.

Mean scores for the sit and reach and vertical jump tests for ADV group were significantly greater than the BEG group. The mean sit and reach score was rated at the 80th percentile and at approximately the 45th percentile for the ADV and BEG groups, respectively (19, p.103). The means for vertical jump were classified at the 50th and 10th percentiles for the ADV and BEG groups (8). The sit-up and one mile walk/run fitness tests approached significance, and these ADV and BEG mean scores for the sit-ups were at the 45th and 30th percentiles (8). The significant fitness performance variables and those approaching significance in this study are field tests that correspond with fitness characteristics that have been recognized as extremely important to skating skills (e.g., lower body flexibility and explosive power) (1, 3, 9, 14, 15, 17, 20, 21, 22, 25, 26, 28). These fitness abilities are essential for skaters to advance to increasingly higher skill levels in the *MITF* ranks. The fitness characteristics and corresponding skating skills focused on with the *MITF* tests are: lower extremity flexibility for extension; explosive lower body power for greater power and speed; greater core strength for upper body posture, carriage and control, and aerobic and anaerobic endurance to maintain all of the previously mentioned skating characteristics throughout the patterned move.

The fitness performance variables hexagon test and push-up test were not significantly different between the groups. This may be explained by the lack of focus placed on these fitness characteristics by the *MITF* disciplines. These tests represent highly developed lower body coordination and upper extremity strength, respectively. Another interpretation for the lack of difference between groups for the full body coordination associated with the hexagon test is that a high degree of coordination may be developed by all skaters regardless of skating ability due to the basic skills needed to ice skate at all. In contrast to these tests, the vertical jump test was different between the groups reflecting its association with *MITF* ratings (see Table 4). In addition, it may be noted that the modified push-up means for the ADV and BEG groups were ranked at the >100th and the 60th percentile, respectively (8) when the skaters were compared with their age-matched counterparts. This may reflect the overall fitness of the children and youth who choose to participate in a sport (e.g., synchronized skating) as compared to their sedentary counterparts. The lack of difference in the wall sit between groups, and greater scores obtained by the BEG group may be attributed to the physical and developmental differences shown in the anthropometric measures (e.g., lower body weight and greater strength to body weight ratio).

All significant correlations were in the expected direction using the *MITF* skating skill levels. Age, weight, height, BMI, sit and reach score, vertical jump height and number of sit-ups all had a positive relationship with skating ability as defined by *MITF* levels. As the anthropometric measures and fitness performance variables increased (more physical development represented better fitness performance), the *MITF* level increased. The one-mile walk/run had an inverse relationship with skating ability (as the run time decreased the *MITF* level increased). Interestingly, all of the same dependent variables that were significantly different between the BEG and ADV groups demonstrated significant relationships with increased skill ability (higher *MITF* level). Additionally, the two variables that approached significance (sit-ups and one-mile walk/run) had significant relationships with skating ability categorized by each *MITF* level versus by skating ability group (ADV vs. BEG). All of the significant variables are indicators of important physical characteristics required for very skilled skating ability on the ice. Further physical development, whether demonstrated through anthropometric traits or fitness performance levels, is correlated with increased skating ability. However, it cannot be determined if physical development is the sole factor in increased skating ability or if this higher level of skating ability can be attributed to the physical fitness a skater may develop through training.

The identification of specific synchronized skating fitness variables is important because off-ice physical development influences on-ice skill ability and injury prevention (13, 15, 25). Distinguishing which areas are developed and which areas need further training can help guide the design and use of more efficient exercise programs. Factors such as sport specific skill development, taking the level of ability and goals into consideration, and incorporating enough recovery time are all important in the construction of appropriate conditioning programs (11, 12). As skaters develop a greater focus on training, greater gains from specialized training may be realized regardless of physical development.

There are clear benefits to youth and adolescents being involved in physical activity at a young age (4, 12). Participating in deliberate practice that is specialized to a specific sport also has further advantages (4). In sports such as figure skating, a high degree of athletic development is needed to master the foundation of skills necessary to participate in and reach peak performance (12). Specializing in a sport is a controversial topic, however, no evidence has been found that specializing can be detrimental to developmental age groups when monitored and appropriately implemented (2). The American Academy of Pediatrics Committee on Sports Medicine and Fitness recommends waiting to specialize in a sport until after reaching the age of puberty (2). Developing a wide base of fundamental motor skills and athletic ability through participation in off-ice activities can have a greater impact on the overall adherence to a physically active and healthy lifestyle (4, 12). Focusing on the implementation of well designed off-ice conditioning programs for synchronized skaters of all ages may aid in the promotion of physically active lifestyles while incorporating motor development and fitness skills in an activity the participants enjoy. As a sport that develops strength, flexibility, and cardiopulmonary endurance, figure skating and more specifically synchronized skating, is an excellent lifelong activity in which to participate (25, 27).

It is clear that additional research is needed for many of the topics in this study. Limitations of the present study include a small sample size, those children and adolescents who volunteered to participate in this study, and no inclusion of a measurement of percentage body fat. Boys did volunteer for the study, but were excluded because of small sample size. An additional component that was not within the scope of this project is the importance of the skater's psychological development, which plays a role in physical activity adherence and sport performance.

Youth synchronized skaters may be characterized by skating abilities (*MITF* levels) as well as anthropometric and fitness performance variables. Skaters who were rated higher for *MITF* levels had greater anthropometric measures and scores for fitness performance variables. Physical development may have affected these performance to skill level relationships, however, data were presented for youth synchronized skaters. Future studies may continue to identify fitness variables that are essential for synchronized skating, and this may assist coaches in the design of sport specific training programs for skating.

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REFERENCES

1. Aleshinsky SY, Podolsky A, McQueen C, Smith A, Van Handel P. Figure skating: Strength and conditioning program for figure skating. Natl Strength Cond Assoc J 10(4): 26-30, 1988.

2. American Academy of Pediatrics, Committee on Sports Medicine and Fitness. Intensive training and sports specialization in young athletes. Pediatrics 106(1):154-157, 2000.

3. Byrne C, Eston R. Figure skating. In: Winter EM, et al., Eds, Sport and Exercise Physiology Testing Guidelines. New York, NY: Routledge, 2007; 310-218.

4. Callender SS. The early specialization of youth in sports. Athletic Training & Sports Health Care 2(6): 255-257, 2010.

5. Harman E, Pandorf C. Principles of test selection and administration. In Baechle TR, Earle RW, Eds, Essentials of strength training and conditioning. Champaign, IL: Human Kinetics, 2000.

6. Harman E, Garhammer J, Pandorf C. Administration, scoring, and interpretation of selected tests. In Baechle TR, Earle RW, Eds, Essentials of strength training and conditioning. Champaign, IL: Human Kinetics, 2000.

7. Hodge K. Trends in Synchronized Skating. 2009 U.S. Figure Skating, Synchronized Skating National Coaches College, 2009.

8. Hoffman, J. Norms for fitness, performance, and health. Champaign, IL: Human Kinetics, 2006.

9. International Skating Union. Section 4: Information. In: ISU medical information booklet. Retrieved from http://ww2.isu.org/medical/info.html. No date.

10. Kjaer M, Larsson B. Physiological profile and incidence of injuries among elite figure skaters. J Sports Sci 10(1): 29-36, 1992.

11. Kuczmarski RJ, Ogden CL, Guo SS. 2000 CDC growth charts for the United States: Methods and development. National Center for Health Statistics. Vital Health Stat 11(246): 1-190, 2002.

12. Landers RQ, Carson RL, Blankenship BT. The promises and pitfalls of sport specialization in youth sport. JOPERD 81(8):14-15, 2010.

13. Lipetz J, Kruse RJ. Injuries and special concerns of female figure skaters. Clin Sports Med 19: 369-380, 2000.

14. Mannix ET, Healy A, Farber MO. Aerobic power of supramaximal endurance of competitive figure skaters. J Sports Med Physical Fit 36(3): 161-168, 1996.

15. Mannix ET, Kollen P, Farber MO. Physiology of Figure Skating. In Garrett WE, Kirkendall DT, Eds, Exercise and sport science. Philadelphia, PA: Lippincott Williams & Wilkins, 2000.

16. Maud PJ, Foster C. Physiological assessment of human fitness. Champaign, IL: Human Kinetics, 2006.

17. McMaster WC, Liddle S, Walsh J. Conditioning program for competitive figure skating. Am J Sports Med 7: 43-47, 1979.

18. Monsma EV, Malina, RM. Anthropometry and somatotype of competitive female figure skaters 11-22 years: Variation by competitive level and discipline. J Sports Med Phys Fit 45:491-500, 2005.

19. Nieman D. Exercise testing and prescription: A health related approach. Boston, MA: McGraw Hill, 2003.

20. Niinimaa V. Figure skating: What do we know about it. Phys Sportsmed 10: 51-56, 1982.

21. Patton SG, Pyke FS, Hahn AG, Telford RD, Tumilty DM. A physiological study of competitive figure skaters. Sports Coach 10: 30-34, 1986.

22. Poe CM. Conditioning for figure skating: Off-ice techniques for on-ice performance. Chicago, IL: Contemporary Books, 2002.

23. Safrit MJ, Wood TM. Introduction to measurement in physical education and exercise science. St. Louis, MO: Mosby, 1995.

24. Safrit MJ. The validity and reliability of fitness tests for children: a review. Pediatr Exerc Sci. 2: 9-28, 1990.

25. Smith AD. The Young Skater. Clin Sports Med 19(4): 741-755, 2000.

26. The Professional Skaters Association. Coach's Guide to Figure Skating. Sports Science and Medicine, 2004.

27. U.S. Department of Health and Human Services, Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report. Retrieved from http://www.health.gov/PAGuidelines/Report, 2008.

28. U.S. Figure Skating 2008 Synchronized Skating Fact Sheet. Retrieved from www.usfsa.org/content/2007-08%20synchro%20fact%20sheet.pdf, 2008.

29. U.S. Figure Skating 2015-2016 Synchronized Skating Fact Sheet. Retrieved from http://www.usfigureskating.org/content/Fact Sheet/2015-16 USFS Factsheet web - no NBC schedule.pdf, 2016.

30. U.S. Figure Skating. The 2011 official U.S. figure skating rulebook. Retrieved from https://www.usfigureskating.org/Content/2011 Rulebook.pdf. 2010.

31. United States Figure Skating. Injury prevention. Retrieved from http://usfigureskating.org/Athletes.asp?id=224. No date.

32. United States Figure Skating. Moves In The Field. Retrieved from http://www.usfsa.org/Shell.asp?sid=42287. No date.