



Relationships among motor skill, perceived self-competence, fitness, and physical activity in young adults

Sarah Carson Sackett*, Elizabeth Skidmore Edwards

Department of Kinesiology, Morrison Bruce Center, James Madison University, 261 Bluestone Dr., MSC 2302, Harrisonburg, VA 22807, USA

ARTICLE INFO

Keywords:

Fundamental motor skill
Physical fitness
Perceived self-competence
Gender differences
College-aged

ABSTRACT

Purpose: This large-scale, exploratory study sought to examine the associations between motor skill proficiency (MSP), perceived self-competence (PC), physical fitness (PF), and self-reported physical activity (PA) to assess the assumption that relationships among these variables found in childhood and adolescence persist into young-adulthood. Specifically, predictors of PF and PA were assessed. Additionally, the contributions body mass index (BMI) and gender made to these relationships, as well as that of process- versus product-oriented motor skills data, were studied. Finally, how these relationships differed by gender was explored.

Methods: Participants' ($n = 448$) MSP was assessed using select measures from the TGMD-2 and the BOT-2, while PF was evaluated using the FitnessGram. Participants also completed surveys to assess PC (SPPCS), PA (past-week MAQ), and demographic information. Height and weight were collected to calculate BMI.

Results: Models predicting physical fitness had good fit to the observed data, with perceived athletic competence, locomotor skill, upper-limb coordination, BMI, and gender accounting for about 75% ($R^2 = 0.748$) of aerobic PF variance and about 48% ($R^2 = 0.476$) of variance in push-up performances. About 18% ($R^2 = 0.178$) of variance in curl-up performances was predicted by perceived athletic competence, locomotor skill, upper-limb coordination, and PA. The PA model demonstrated weaker predictive power, with only about 10% ($R^2 = 0.097$) of variance explained. When considering male and female models separately, female models demonstrated better fit when predicting all PF and PA outcome variables. BMI and gender operated as significant predictors to differing degrees across the various models.

Conclusions: There is compelling evidence to believe relationships found among MSP, PC, PF, and PA in childhood and adolescence also exist in early adulthood. However, differences in the roles of gender and physical fitness versus physical activity are likely to exist.

1. Introduction

Substantial evidence indicates that physical fitness (e.g., cardiovascular fitness and muscular strength and endurance) independently influence health risks for chronic disease such as cardiovascular disease and cancer (Eisenmann, Welk, Wickel, & Blair, 2007; Ruiz et al., 2009), with the potential for these health risks to emerge in childhood (Janssen & LeBlanc, 2010). With that tendency in mind, past research has sought to establish relationships between these variables and has identified independent associations between motor skill proficiency (MSP) and physical fitness (PF; e.g., Cairney, Veldhuizen, King-Dowling, Faught, & Hay,

* Corresponding author.

E-mail addresses: carsonsa@jmu.edu (S. Carson Sackett), edwardes@jmu.edu (E.S. Edwards).

<https://doi.org/10.1016/j.humov.2019.04.015>

Received 30 November 2018; Received in revised form 6 March 2019; Accepted 28 April 2019

Available online 06 May 2019

0167-9457/ © 2019 Elsevier B.V. All rights reserved.

2017; Haga, 2009; Haga, Gísladóttir, & Sigmundsson, 2015; Stodden, Langendorfer, & Robertson, 2009), as well as MSP and physical activity (PA; e.g., Logan, Kipling Webster, Getchell, Pfeiffer, & Robinson, 2015; Okely, Booth, & Patterson, 2001; Wrotniak, Epstein, Dorti, Jones, & Kondilis, 2006) in children, adolescents, and young adults. Furthermore, childhood MSP has been positively correlated with PF and PA levels assessed later in adolescence, suggesting these relationships persist through early phases of the lifespan (e.g., Barnett, Morgan, van Beurden, & Beard, 2008; Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Logan et al., 2015). Additionally, the motor proficiency-fitness relationship may track into adulthood, with some health outcomes (e.g., low bone mineral density, cardiovascular disease) becoming even more impaired among low MSP groups (Cantell, Crawford, & Doyle-Baker, 2008).

The proposed relationships among PA, PF, and MSP can be viewed as operating in positive or negative feedback loops (Hands & Larkin, 2002; Stodden et al., 2008). Strong motor skills may make PA more enjoyable and fulfilling, leading to more frequent engagement as well as further development of MSP and enhanced PF. Conversely, the activity deficit hypothesis depicts a debilitating cycle for those individuals on the lower end of the motor skill spectrum. Here, individuals view themselves as less competent than their peers, avoid publicly displaying their inadequacies or are excluded from physical activities by peers, and fail to seek out challenging physical activities that could help refine their skills and lead to increased fitness and reduced health issues. The relationship between all three variables is predicted to strengthen with age; however, it is unclear at what point this increase may plateau or reverse. In a 2010 review, Lubans and colleagues identified empirical support for positive and meaningful relationships between fundamental MSP and PA as well as MSP and measures of cardiorespiratory PF in children and adolescents, substantiating the proposed associations (Lubans, Morgan, Cliff, Barnett, & Okely, 2010).

As described above, these positive and negative feedback loops also include psychological components, including perceived self-competence (PC; Hands & Larkin, 2002; Stodden et al., 2008). PC represents a self-evaluation of one's abilities in a variety of domains, including social, intellectual, and movement skills, as well as attributes like physical appearance (Harter, 1990). Measures of PC also tend to tap into a sense of one's global self-worth or self-esteem. Previous research has demonstrated that individuals who participate in regular PA and have higher levels of PF tend to have higher levels of perceived global and physical competence (Raudsepp, Liblik, & Hannus, 2002). Conversely, and unfortunately, the mere perception of movement skill inadequacies may be sufficient enough to inhibit the adoption of an active lifestyle, leading to decreased levels of health and fitness (Southall, Okley, & Steele, 2004; Welk & Eklund, 2005). Positive linear correlations have also been found between PC and fundamental MSP (Raudsepp et al., 2002; Robinson, 2011). While the relationships among PF and PA levels, MSP, and PC are logical, fewer studies have empirically investigated the association among all factors (Bürgi et al., 2011). A notable exception is from Barnett, Morgan et al., 2008 who reported two models that indicated a significant amount of variation in adolescent PA and PF levels (18% and 30%, respectively) were predicted by childhood MSP (i.e., object control) and PC. These relationships were mediated (and nearly doubled in strength) after the inclusion of adolescent perceived sports competence.

The relationships among PF, PA, MSP, and PC may also be mediated by gender. However, research is inconclusive on whether the relationship between PF and MSP is stronger among male or female children and adolescents (Gísladóttir, Haga, & Sigmundsson, 2014; Okely et al., 2001). When examining potential associations, significant relationships among PF, MSP, and differing measures of PC have been reported; however, the strength and ranking of these correlations differed between males and females (Vedul-Kjelsås, Sigmundsson, Stensdotter, & Haga, 2012). For example, in the Vedul-Kjelsås et al. (2012) study, PF was correlated most strongly with perception of athletic competence in males and with perception of social acceptance in females.

The present study aims to fill important gaps in the current literature. First, relatively little attention has been paid to studying how physical fitness and motor competence relate in late adolescent and young adult populations (Gísladóttir et al., 2014). While some have proposed these relationships found in younger populations could be amplified with age (Stodden et al., 2009), few empirical projects have verified these suppositions. Even fewer have considered all variables identified by these models (i.e., PA, PF, MSP, and PC; Stodden et al., 2009; Vedul-Kjelsås et al., 2012) or related gender differences that may exist within adult populations. Research in this area is also warranted because many related studies have had limitations including inconsistent methodologies (e.g., process- versus product-oriented assessments of MSP) within and among studies (Barnett et al., 2016; Okely et al., 2001; Sgro, Quinto, Pignato, & Lipoma, 2016). With a lack of research that has considered MSP from both the process (qualitative technique of how the motor skill is performed) and product (movement results such as the accuracy of a throw or speed of a run) perspectives, recommendations for how motor skills can be assessed and instructed to incur associated benefits (e.g., greater PA engagement, PF outcomes) remains unclear. Therefore, the purpose of the present study was to conduct a large-scale project that investigated the relationships among motor skill competence (using both product and process measures), physical fitness, self-reported physical activity, and perceived self-competence in young adults. Specifically, predictors of physical fitness and physical activity were assessed. Finally, the roles of BMI and gender in the predictive models were explored and gender-specific models were investigated.

2. Methods

2.1. Participants

A total of 648 college students from 29 sections of a general education course at a Mid-Atlantic public university were recruited for this study. Students had to be 18 years of age or older to qualify for participation.

2.2. Measures

2.2.1. Physical fitness

The FitnessGram (Meredith & Welk, 2010) was used to collect data on the indices of aerobic fitness (Progressive Aerobic Cardiovascular Endurance Run; PACER) and muscular strength and endurance (curl-up, push-up). Measures of height and weight were also collected to calculate participants' body mass index (BMI). While the FitnessGram is most commonly used with children and adolescents, this instrument was deemed appropriate for the present study's purposes due to its recognition of and normative data provided for the 17+ age group. As a conservative measure, only raw scores were utilized by the present study since less reliability data are available for the age-based normative fitness groups (i.e., healthy fitness zones) for young adults. Furthermore, previous research has found good reliability for the PACER (Beets & Pitetti, 2006), push-up (Jackson, Fromme, Plitt, & Mercer, 1994), and curl-up (Robertson & Magnusdottir, 1987) tests in high school and college-aged students.

2.2.2. Motor skill proficiency

As a process-measure of MSP, researchers administered the Test of Gross Motor Development (2nd Edition; TGMD-2; Ulrich, 2000) to assess six locomotor (i.e., run, gallop, hop, leap, horizontal jump, slide) and six object control skills (i.e., striking a stationary ball, stationary dribble, catch, kick, overhand throw, underhand roll). A shortcoming of the TGMD-2 for the purposes of the present study are that it only provides normative data through age 10. However, since there is a dearth of process-oriented motor skill proficiency measures validated with adolescents and adults, it is not uncommon for researchers to use instruments standardized for children with older populations (Hands, Licari, & Piek, 2015), and there is some evidence that the TGMD-2, specifically, shows suitable reliability and validity up through early adolescence (Issartel et al., 2017). To mediate this limitation, only raw subscale scores (as opposed to converting the data to percentiles or age-equivalent scores) were used to accommodate the lack of normative data for our population.

As a product-measure of MSP, researchers also administered the Bruininks-Oseretsky Test of Motor Proficiency (2nd Edition; BOT-2; Bruininks & Bruininks, 2005). To remain parallel with the TGMD-2 assessments, only select gross motor outcome measures were utilized (i.e., upper-limb coordination, running speed, agility). Inter-rater reliabilities for the BOT-2 have been very strong ($r = 0.98$), with suitable test-re-test reliability for 13–21 year olds ($r = 0.75$; Hands et al., 2015).

2.2.3. Self-reported physical activity

Physical activity was assessed using the Past-Week Modifiable Activity Questionnaire (PWMAQ; Gabriel, McClain, Schmid, Storti, & Ainsworth, 2011), which measures participants' engagement in a variety of activities over the previous seven days, while also assessing their time spent sitting both in and out of work. Results were calculated and expressed as MET hours per week. The PWMAQ (as administered by interviewer) has demonstrated adequate test-retest reliability ($ICC = 0.77$) and moderately strong and significant associations with objective accelerometer data in adults (Gabriel et al., 2011).

2.2.4. Perceived self-competence

Perceived self-competence was assessed using the Self-Perception Profile for College Students (SPPCS; Neuman & Harter, 1986). This questionnaire is a 54-item survey designed to evaluate college students' perceptions of themselves across 13 domains (i.e., creativity, intellectual ability, scholastic competence, job competence, athletic competence, appearance, romantic relationships, social acceptance, close friendships, parent relationships, finding humor in one's life, global self-worth), with only the Job Competence subscale scoring a reliability coefficient below $\alpha = 0.79$ (range = -0.74 to 0.95 ; Masciuch, McRae, & Young, 1990).

2.2.5. Height and weight

Height and weight measurements were taken by a member of the research staff after the participant had removed their shoes and any additional layers (e.g. sweatshirts, jackets). Height was measured using a stadiometer, while weight was measured on a digital platform.

2.3. Procedures

After obtaining approval from the researchers' Institutional Review Board, participants were recruited via in-person communication (e.g., visits to classes by the research staff) and through the lead instructors of the general education courses. All testing was held during regularly scheduled class periods, and students who opted not to participate completed their normal physical activity lab activities. No incentives were offered for student participation. Over the course of three class periods, qualified students who consented to participate completed the battery of assessments in the following order. During the first day, participants (in groups of 8 or less) rotated through four stations that consisted of the PACER and push-up assessments, the curl-up and sit-and-reach assessments, and completion of the PWMAQ, SPPCS, and a demographic questionnaire that collected data on date of birth, gender, race/ethnicity, and year in school. These questionnaires were completed in a gymnasium with as much room to spread out as desired and with research staff actively overseeing this process to minimize discussion and comparison. The second day of testing included the completion of four rotating stations of the TGMD-2 skills tests (i.e., leap/jump/slide, kick/throw/roll, run/gallop/hop, strike/dribble/catch). On the final testing day, participants completed a rotation of four stations, during which select BOT-2 skills tests were administered (i.e., strength I [standing long jump/push-ups/sit-ups], strength II [wall sit/v-up], speed/agility, upper-limb coordination). To minimize fatigue as a potential confounder, both the organization of tests within a station, as well as rotation between

stations, were organized so consecutive tests that put demands on the same body segment were minimized. Across all testing days, trained assessors were responsible for collecting data from all participants at a single station. Additionally, the TGMD-2 stations were video recorded to allow the assessors time to rate all fundamental motor skills, using this complex process-oriented tool, in a more controlled environment. Two senior investigators trained in the use of the TGMD-2 scored all videos independently and then reviewed the recordings again to discuss and come to consensus on any discrepancies in initial scoring results.

2.4. Statistical analyses

Independent samples t-tests were used to examine differences in fitness and body composition scores between participants with complete and incomplete motor skill data. Motor skill data were summed into raw subscale scores for locomotor and object control skills (TGMD-2), upper-limb coordination, and speed/agility (BOT-2) as directed by their respective testing manuals (Bruininks & Bruininks, 2005; Ulrich, 2000). However, only raw subscale scores were used, as opposed to norm-referenced scores, given that normative data are not available for the age range included in this study. PC data were limited to the subscales of appearance, athletic competence, and global self-worth due to their relevance to the physically-oriented outcome variables of interest. Data were analyzed using the statistical program SPSS (v. 24, IBM Analytics, Armonk, New York). Kendall Rank (nonparametric data) correlations were utilized to examine initial relationships among measures of CV fitness, muscular strength and endurance, subscale scores for MSP, and the above mentioned PC subscale scores. Stepwise multiple regression analyses were used to identify variables which significantly predict cardiovascular fitness, muscular strength and endurance, and self-reported physical activity. For each model, variables that significantly correlated with the outcome variable were included in the stepwise analysis. Analyses were run by gender and in aggregate. Alpha was set *a priori* at 0.05.

3. Results

Participants included 648 out of 843 (80.9% response rate) of enrolled undergraduate students who consented to participate in this study and completed at least one day of data collection. These students were almost all traditionally-aged college students (age: 18.96 ± 1.50 yrs), with the majority (73.8%) being freshmen or sophomores. The sample was not especially diverse, with the following representations: white (82.6%), black (3.5%), East Asian (6.6%), Latino/Hispanic (2.9%), Middle Eastern (1.4%), Hawaiian/Pacific Islander (0.3%), South Asian/Indian (1.0%). However, this distribution aligns with the demographic breakdown of the university's student body. Four hundred and forty-eight students (69% of total participants) had complete data on all variables and were included in the analyses. Reasons for not completing all data collection were varied, but primarily included class absences on days of subsequent testing and/or unrelated injuries or illnesses that prevented full completion of all testing sessions. There were no differences in mean scores for PACER, curl-ups, push-ups, self-reported PA, or BMI between students with complete data and those excluded for incomplete data (data not reported). Means and standard deviations of each included variable are presented in Table 1. When examining relationships between measures, almost all measures of MSP and PC were positively correlated with PF and PA outcome measures ($p < 0.05$; Table 2); however, the strength of these correlations varied broadly. Additionally, BMI was negatively correlated with PACER, but there were no significant correlations between BMI and PA, push-up, or curl-up ($p > 0.05$) scores.

3.1. Physical fitness

3.1.1. Cardiovascular fitness

PACER performance was significantly correlated with BMI, self-reported PA, and the subscale scores for physical appearance, athletic competence, global self-worth, upper-limb coordination, speed/agility, locomotor, and object control skills. A significant

Table 1
Descriptive statistics for all participants with complete data.

| Construct | Variable | All (n = 448) | Females (n = 237) | Males (n = 211) | P |
|------------------------|---------------------------------|--------------------|--------------------|--------------------|----------|
| Physical Fitness | PACER (laps) | 47.36 \pm 19.56 | 36.31 \pm 14.21 | 59.78 \pm 17.15 | < 0.001* |
| | Push-ups (reps) | 16.99 \pm 10.74 | 11.39 \pm 7.74 | 23.81 \pm 9.92 | 0.026* |
| | Curl-ups (reps) | 49.96 \pm 23.59 | 46.55 \pm 23.77 | 54.03 \pm 22.75 | n.s. |
| Motor Skill Competence | Upper-Limb Coordination (BOT-2) | 106.13 \pm 18.69 | 101.83 \pm 13.96 | 110.98 \pm 21.90 | < 0.001* |
| | Speed/Agility (BOT-2) | 40.71 \pm 3.91 | 40.24 \pm 4.03 | 41.25 \pm 3.71 | 0.006* |
| | Locomotor (TGMD-2) | 40.90 \pm 3.50 | 40.79 \pm 3.70 | 41.03 \pm 3.27 | n.s. |
| | Object Control (TGMD-2) | 40.07 \pm 3.68 | 38.90 \pm 3.71 | 41.38 \pm 3.19 | < 0.001* |
| Self-Competence | Appearance | 2.53 \pm 0.47 | 2.48 \pm 0.49 | 2.59 \pm 0.45 | 0.017* |
| | Athletic Competence | 2.93 \pm 0.73 | 2.76 \pm 0.74 | 3.11 \pm 0.68 | < 0.001* |
| | Global Self-Worth | 3.23 \pm 0.53 | 3.25 \pm 0.52 | 3.19 \pm 0.54 | n.s. |
| Body Mass Index | BMI (kg/m ²) | 23.30 \pm 3.46 | 22.99 \pm 3.35 | 23.65 \pm 3.57 | 0.046* |
| Physical Activity | PA: Total MET hr/week | 33.49 \pm 25.82 | 28.84 \pm 20.71 | 38.72 \pm 29.77 | < 0.001 |

*Significantly different between genders; n.s. indicates a non-significant difference; PACER: Progressive Aerobic Cardiovascular Endurance Run; BOT-2: Bruininks-Oseretsky Test of Motor Proficiency 2; TGMD-2: Test of Gross Motor Development 2; PA: Physical activity; SPPCS: Self-Perception Profile for College Students; BMI: Body mass index; PA: Physical Activity; MET: Metabolic equivalent.

Table 2

Correlations among measures of cardiovascular fitness, self-reported physical activity, motor skill competence, perceived self-competence, and body mass index.

| Variable | PACER | Push-Ups | Curl-Ups | Upper-Limb Coordination | Speed/Agility | Locomotor | Object Control | Appearance | Athletic Competence | Global Self-Worth | BMI | PA |
|-----------------|----------|----------|----------|-------------------------|---------------|-----------|----------------|------------|---------------------|-------------------|-------|----|
| PACER | 1 | | | | | | | | | | | |
| Push-Ups | 0.492** | 1 | | | | | | | | | | |
| Curl-Ups | 0.297** | 0.316** | 1 | | | | | | | | | |
| UL Coordination | 0.459** | 0.484** | 0.268** | 1 | | | | | | | | |
| Speed/Agility | 0.108** | 0.141** | 0.059 | 0.218** | 1 | | | | | | | |
| Locomotor | 0.193** | 0.195** | 0.186** | 0.267** | 0.063 | 1 | | | | | | |
| Object Control | 0.232** | 0.237** | 0.112** | 0.247** | 0.105** | 0.155** | 1 | | | | | |
| Appearance | 0.156** | 0.147** | 0.095** | 0.124** | 0.020 | 0.072* | 0.033 | 1 | | | | |
| AthCom | 0.356** | 0.331** | 0.224** | 0.344** | 0.141** | 0.230** | 0.226** | 0.267** | 1 | | | |
| GSW | 0.062* | 0.080** | 0.092** | 0.061* | 0.022 | 0.076* | 0.032 | 0.365** | 0.321** | 1 | | |
| BMI | -0.078** | -0.034 | -0.039 | 0.022 | -0.011 | 0.013 | 0.076* | -0.224** | -0.033 | -0.068* | 1 | |
| PA | 0.201** | 0.170** | 0.175** | 0.173** | 0.061* | 0.050 | 0.122** | 0.063* | 0.205** | 0.076** | 0.002 | 1 |

* $p < 0.05$; ** $p < 0.01$; PACER: Progressive Aerobic Cardiovascular Endurance Run; UL: Upper-limb; AthCom: Athletic Competence; GSW: Global Self-Worth; BMI: Body Mass Index; PA: Physical activity;

amount of variation in PACER scores (e.g. how many laps were successfully completed) was explained by these variables when examining the sample as a whole ($R^2 = 0.748$; $F(5, 442) = 112.58$, $p < 0.001$), females alone ($R^2 = 0.632$; $F(4, 232) = 38.66$, $p < 0.001$), or males alone ($R^2 = 0.518$; $F(3, 207) = 25.37$, $p < 0.001$). Athletic competence, BMI, and the locomotor subscale were all predictive of PACER scores for the sample as a whole, females only, and males only (Table 3). When examining the sample in aggregate, the locomotor subscale and upper-limb coordination subscale were also significant factors in predicting PACER. When examined by gender, only the locomotor subscale remained significant. However, PA was also a significant predictor of PACER scores among females, but not males.

3.1.2. Muscular strength and endurance

Push-up performance was significantly correlated with physical appearance, athletic competence, global self-worth, upper-limb coordination, speed/agility, locomotor skills, object control skills, and PA. Therefore, these variables were included in the stepwise regression. A significant amount of variance in the number of push-ups performed was explained by these variables across gender ($R^2 = 0.476$; $F(5, 435) = 79.18$, $p < 0.001$), females alone ($R^2 = 0.239$; $F(3, 234) = 24.53$, $p < 0.001$), or males alone ($R^2 = 0.201$; $F(3, 199) = 16.73$, $p < 0.001$). Athletic competence and the upper-limb coordination subscale were significant predictor variables in all three models for predicting push-up performance; however, the locomotor subscale was only significant for the models including both genders and females only (Table 4). Similarly, BMI was only significant in the models for both genders and males only.

Curl-up performance was significant correlated with self-reported PA, as well as subscale scores for physical appearance, athletic competence, global self-worth, locomotor skills, object control skills, upper-limb coordination, and PA. Therefore, these variables were included in the stepwise regression. Variance in core muscular strength and endurance, as measured by curl-ups, was

Table 3

Predicting Cardiovascular Fitness Outcomes from Motor Skill Competence, Perceived Self-Competence, Self-Reported Physical Activity, and Body Mass Index.

| Sample | R^2 | Variable Name | B | SE B | β | t | p |
|-------------------|-------|----------------------------------|--------|--------|---------|--------|-------|
| All (n = 448) | 0.748 | (Constant) | 7.619 | 8.584 | | 0.888 | 0.375 |
| | | Gender | 20.635 | 1.313 | 0.527 | 15.716 | 0.000 |
| | | Athletic Competence | 7.501 | 0.932 | 0.281 | 8.047 | 0.000 |
| | | BMI | -1.233 | 0.181 | -0.218 | -6.808 | 0.000 |
| | | Locomotor Subscale | 0.664 | 0.191 | 0.119 | 3.475 | 0.001 |
| | | Upper-Limb Coordination Subscale | 0.091 | 0.036 | 0.087 | 2.515 | 0.012 |
| Females (n = 237) | 0.632 | (Constant) | 8.022 | 9.798 | | 0.819 | 0.414 |
| | | Athletic Competence | 7.107 | 1.076 | 0.371 | 6.603 | 0.000 |
| | | BMI | -1.026 | 0.218 | -0.242 | -4.696 | 0.000 |
| | | PA (Total MET/hr/week) | 0.149 | 0.037 | 0.217 | 4.064 | 0.000 |
| | | Locomotor Subscale | 0.685 | 0.205 | 0.178 | 3.337 | 0.001 |
| Males (n = 211) | 0.518 | (Constant) | 29.066 | 14.440 | | 2.013 | 0.045 |
| | | Athletic Competence | 6.991 | 1.620 | 0.276 | 4.316 | 0.000 |
| | | BMI | -1.463 | 0.290 | -0.304 | -5.048 | 0.000 |
| | | Locomotor Subscale | 1.061 | 0.331 | 0.202 | 3.202 | 0.002 |

BMI: Body Mass Index; PA: Physical Activity; MET: Metabolic Equivalent.

Table 4

Predicting Push-Up Performance from Motor Skill Competence, Perceived Self-Competence, Self-Reported Physical Activity, and Body Mass Index.

| Sample | R ² | | B | SE B | β | t | p |
|-------------------|----------------|----------------------------------|---------|-------|--------|--------|-------|
| All (n = 448) | 0.476 | (Constant) | -10.130 | 5.133 | | -1.973 | 0.049 |
| | | Gender | 10.666 | 0.788 | 0.498 | 13.527 | 0.000 |
| | | Athletic Competence | 3.284 | 0.559 | 0.226 | 5.875 | 0.000 |
| | | Upper-Limb Coordination Subscale | 0.081 | 0.022 | 0.142 | 3.738 | 0.000 |
| | | BMI | -0.387 | 0.108 | -0.126 | -3.573 | 0.000 |
| | | Locomotor Subscale | 0.322 | 0.114 | 0.106 | 2.827 | 0.005 |
| Females (n = 237) | 0.239 | (Constant) | -24.758 | 5.261 | | -4.706 | 0.000 |
| | | Upper-Limb Coordination Subscale | 0.146 | 0.036 | 0.259 | 4.119 | 0.000 |
| | | Athletic Competence | 2.386 | 0.664 | 0.225 | 3.595 | 0.000 |
| | | Locomotor Subscale | 0.359 | 0.130 | 0.170 | 2.763 | 0.006 |
| Males (n = 211) | 0.201 | (Constant) | 12.290 | 5.905 | | 2.081 | 0.039 |
| | | Athletic Competence | 4.732 | 0.920 | 0.333 | 5.141 | 0.000 |
| | | BMI | -0.463 | 0.170 | -0.174 | -2.723 | 0.007 |
| | | Upper-Limb Coordination Subscale | 0.069 | 0.028 | 0.161 | 2.506 | 0.013 |

BMI: Body Mass Index.

significantly explained by PA, MSP, and PC variables when examined with genders combined ($R^2 = 0.178$; $F(4, 432) = 23.46$, $p < 0.001$), females alone ($R^2 = 0.246$; $F(4, 229) = 18.65$, $p < 0.001$), and males alone ($R^2 = 0.128$; $F(3, 199) = 9.74$, $p < 0.001$). The upper-limb coordination and locomotor subscales were significant predictor variables across all three models (Table 5) used to predict curl-up performance. PA and athletic competence were significant predictors for both the combined and the female only analyses. Global self-worth was a significant predictor of curl-up performance for males.

3.2. Self-reported physical activity

Self-reported PA was significantly correlated with PACER scores, as well as subscale scores for upper-limb coordination, speed/ability, object control, appearance, athletic competence, and global self-worth. A significant amount of the variance in self-reported PA was predicted by PC, PF, and MSP variables for the whole sample ($R^2 = 0.097$; $F(2, 445) = 23.80$, $p < 0.001$), females only ($R^2 = 0.193$; $F(5, 231) = 11.08$, $p < 0.001$) and males only ($R^2 = 0.049$; $F(1, 209) = 10.72$, $p = 0.001$), although it is noteworthy that a lower amount of variance in self-reported PA was explained when compared to the PACER models. Only athletic competence and PACER scores were significantly predictive of self-reported PA among the whole sample, with athletic competence being significant for the male-only analysis (Table 6). The model for predicting self-reported PA among females consisted of more significant predictor variables, including measures of cardiovascular fitness, MSP, and PC.

4. Discussion

To help explore how the relationships previously established by Hands and Larkin (2002) and Stodden et al. (2008) in childhood and adolescence may present later in life, the present study investigated associations among motor skill proficiency (MSP; assessed with process- and product-focused measures), physical fitness (PF), self-reported physical activity (PA), and perceived self-

Table 5

Predicting Curl-Up Performance from Motor Skill Competence, Perceived Self-Competence, Self-Reported Physical Activity, and Body Mass Index.

| Sample | R ² | | B | SE B | β | t | p |
|----------------------------------|----------------|----------------------------------|---------|------------|---------|--------|-------|
| All (n = 448) | 0.178 | (Constant) | -33.256 | 12.062 | | -2.757 | 0.006 |
| | | Upper-Limb Coordination Subscale | 0.286 | 0.058 | 0.229 | 4.891 | 0.000 |
| | | Athletic Competence | 4.005 | 1.555 | 0.124 | 2.575 | 0.010 |
| | | PA (Total MET/hr/week) | 0.134 | 0.042 | 0.145 | 3.179 | 0.002 |
| | | Locomotor Subscale | 0.911 | 0.312 | 0.138 | 2.916 | 0.004 |
| | | Females (n = 237) | 0.246 | (Constant) | -47.755 | 15.672 | |
| Upper-Limb Coordination Subscale | 0.365 | 0.107 | | 0.219 | 3.417 | 0.001 | |
| PA (Total MET/hr/week) | 0.277 | 0.069 | | 0.245 | 4.021 | 0.000 | |
| Locomotor Subscale | 0.931 | 0.390 | | 0.150 | 2.390 | 0.018 | |
| Athletic Competence | 4.309 | 2.074 | | 0.135 | 2.078 | 0.039 | |
| Males (n = 211) | 0.128 | (Constant) | -34.478 | 19.921 | | -1.731 | 0.085 |
| | | Upper-Limb Coordination Subscale | 0.216 | 0.072 | 0.209 | 2.992 | 0.003 |
| | | Locomotor Subscale | 1.093 | 0.490 | 0.156 | 2.229 | 0.027 |
| | | Global Self-Worth | 6.174 | 2.851 | 0.147 | 2.165 | 0.032 |

PA: Physical Activity.

Table 6

Predicting Self-Reported Physical Activity from Cardiovascular Fitness Outcomes, Motor Skill Competence, Perceived Self-Competence, and Body Mass Index.

| Sample | R ² | | B | SE B | β | t | p |
|-------------------|----------------|-------------------------|---------|--------|--------|--------|-------|
| All (n = 448) | 0.097 | (Constant) | 2.754 | 4.830 | | 0.570 | 0.569 |
| | | Athletic Competence | 7.213 | 1.827 | 0.205 | 3.948 | 0.000 |
| | | PACER | 0.203 | 0.068 | 0.154 | 2.963 | 0.003 |
| Females (n = 237) | 0.193 | (Constant) | -17.515 | 18.600 | | -0.942 | 0.347 |
| | | PACER | 0.435 | 0.096 | 0.299 | 4.557 | 0.000 |
| | | Global Self-Worth | 6.117 | 2.385 | 0.154 | 2.565 | 0.011 |
| | | Object Control Subscale | 0.857 | 0.352 | 0.153 | 2.438 | 0.016 |
| | | Locomotor Subscale | -1.060 | 0.366 | -0.189 | -2.894 | 0.004 |
| | | Upper-Limb Coordination | 0.201 | 0.097 | 0.136 | 2.078 | 0.039 |
| Males (n = 211) | 0.049 | (Constant) | 8.437 | 9.462 | | 0.892 | 0.374 |
| | | Athletic Competence | 9.718 | 2.968 | 0.221 | 3.275 | 0.001 |

PACER: Progressive Aerobic Cardiovascular Endurance Run.

competence (PC) in a sample of young adults. Additionally, the predictive power of BMI and gender were considered, and differences in male versus female models were explored.

4.1. Predicting physical fitness

A review of the full models predicting PF indicated that variables representing MSP and PC accounted for a significant amount of variance in cardiovascular fitness as well as measures of muscular strength and endurance. While there was relative consistency in the variables that best predicted these PF outcomes, the strength of the models varied considerably. Cardiovascular fitness (as assessed by the PACER run) had a large amount of variance explained (i.e., 74.8%), while muscular strength and endurance as measured by the push-up and curl up tests only had moderate to weak predictive power (i.e., 47.6% and 17.8%, respectively). Some of the lack of ability to explain variance among the curl-up results is likely a result of this test maxing out at 75 curl-ups (Meredith & Welk, 2010), while the push-up test has no pre-defined ceiling. With previous research looking at correlations between PF, PA, MSP, and PC dyads and/or PF as a combined score of several fitness indices, fully compatible models are not available to fully support these discrepancies. However, the results of the present study are similar to the work of others such as Stodden et al. (2009) who reported that product-measures of fundamental motor skills (i.e., throwing, kicking, and jumping distances, speeds) accounted for 79% of the variance in a composite PF score (i.e., cardiovascular endurance, muscular strength and endurance, body composition) in a sample of college-aged adults.

Unlike Stodden and colleagues, the present study also verified the predictive power of process-oriented measures of MSP (i.e., locomotor skill) as well as the contributions of these variables to all three PF factors. Specifically, predictor variables that were included in all three of the full PF models were perceived athletic competence (PC), locomotor scores (which included process-oriented assessments of the run, gallop, slide, leap, hop, and jump; MSP), and upper-limb coordination scores (which reflected product-oriented measures of catching, throwing, and dribbling; MSP). These findings support and build upon previous research that has substantiated cardiovascular and muscular PF, MSP, and PC links in children and adolescent populations (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Hardy, Reinten-Reynolds, Espinel, Zask, & Okley, 2012; Raudsepp et al., 2002; Vedul-Kjelsås et al., 2012). It would be logical to assume, then, that the relationships between these variables that help or hinder fitness in youth continue to play similar roles in older populations. Measures to optimize and maintain movement skills and movement-related self-perceptions during childhood and adolescence may help establish these benefits and provide a comprehensive approach to sustaining fitness-related health into adulthood.

Although it only served as a significant predictor for the cardiovascular and push-up PF models, BMI was one of the largest contributors to the variance explained in these two analyses. In children and adolescent populations, previous research has reported direct negative associations between high BMI and PF (Beets, Pitetti, & Cardinal, 2005; Kim et al., 2005), as well as indirect and negative associations assumed through correlations between high BMI and low MSP (Barnett et al., 2016; Duncan, Bryant, & Stodden, 2017; Hardy et al., 2012; Robinson, 2011) and high BMI and low PC (Morano, Colella, Robazza, Bortoli, & Capranica, 2011). The BMI and fitness relationships in the present study make some intuitive sense as higher BMI/mass was more likely to have a significant relationship with fitness assessments for which the ability to bear one's weight served as a greater a constraint (i.e., running and push-ups). More surprising was the complete absence of BMI as a predictor for the PA model due to the centrality of body composition in the Hands and Larkin (2002) and Stodden et al. (2008) models; however, this lack of fit was not an issue isolated to BMI when considering predictor variables in PA model.

4.2. Predicting physical activity

Only about 10% of variance was explained by the PA model, and was due to the inclusion of the perceived athletic competence (PC) and cardiovascular PF variables. Unlike the PF models, no measures of MSP were maintained in this model, nor did gender or

BMI serve as significant predictors. This finding fails to support the evidence that has demonstrated MSP and PA are positively related, with more competent movers being more likely to engage in higher rates of PA (Haga et al., 2015; Logan et al., 2015; Lubans et al., 2010; Stodden et al., 2008) as well as links established between PA and BMI (Kimm et al., 2005) and PA and gender (Troiano et al., 2008). It also calls into question previous findings that the positive MSP-PA relationship found in childhood tracks into adolescence (and beyond) (Barnett et al., 2009) and that measures of body composition play a significant role in this relationship (Cairney, Hay, Faught, & Hawes, 2005).

When considering PC as a predictor of PA, the present results better mirror the positive associations found in children, adolescents, and young adults (Babic et al., 2014; Jekauc, Wagner, Herrmann, Hegazy, & Woll, 2017). It has been suggested that PC influences PA due to its impact on effort and persistence in physical activity settings (Papaioannou, 1997). In combination with actual MSP, PC is believed to influence participation in future PA engagement as well (Robinson, 2011). It appears, then, that enhancing MSP and athletic PC may be a fruitful avenue for enhancing PA in young adults, especially since a positive self-concept and related positive movement experiences seem particularly meaningful during the transition from adolescence to adulthood (Jekauc et al., 2017). However, the relatively weak correlations between PA and the other variables considered in the present study as well as the fact only two variables were maintained in this model lends some support to claims suggesting a focus on PA is the leading mechanism for increasing health and wellness may be misdirected (e.g., Hands, Larkin, Parker, Straker, & Perry, 2009). Instead, it may be more a more accurate depiction of the relationship between these variables to view enhanced MSP and PC factors as the mechanisms impacting health-related PF (somewhat independently of PA levels) in young adults.

4.3. Gender-specific models

While gender was only included as a significant predictor in the cardiovascular and push-up PF models, results from the demographic analyses revealed telling trends in gender differences found along the PF, MSP, and PC factors. In line with previous studies (American College of Sports Medicine, 2018), males demonstrated higher levels of cardiovascular fitness and muscular strength/endurance. Males also demonstrated significantly better performances in object control measures, which mirrors findings in children and adolescent populations (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Hardy et al., 2012). Parallel to much of the previous research (Hume et al., 2008), no significant gender differences were found in locomotor skill proficiency. However, males' locomotor skills trended higher than those of females, and male performances of speed and agility were significantly higher than females, which reflected superior product-oriented measures of locomotor skills. Finally, males reported higher levels on two of the three PC domains (i.e., physical appearance and athletic competence), which supports findings that males tend to have higher self-perceptions of physical competence than their female counterparts (Robinson, 2011). The existence and consistency of these trends that favored males over females compelled a closer look at how the PF, PA, PC, and MSP variables may or may not have related differently between the two genders.

When considering the cardiovascular fitness models for males and females separately, female PF was more strongly predicted than that of males. However, athletic competence, BMI, and locomotor scores operated similarly in strength and direction for the two models. The difference in overall predictive power between the genders was at least partially due to PA serving as a significant predictor for female PACER performances only. Interestingly, upper-limb coordination dropped out of the model for both males and females, which runs counter to growing evidence that object-control measures of MSP are more predictive of PF (and PA) than locomotor skill (Barnett et al., 2016). While the relative strengths of the above relationships were not assessed over time in the present study, the results support previous research that suggests the associations that exist in childhood and early adolescence (Haga, 2009) may also exist in later adolescence and beyond.

The female-specific models for muscular strength and endurance also predicted more variance than the male models, and these models illustrated more discrepancies in predictors than the gender-specific models for cardiovascular PF. Only upper-limb coordination (MSP) and athletic competence (PC) served as significant predictors for push-up scores for both genders. The models for curl-up demonstrated even more gender-related disparities in terms of explanatory power (with the female model explaining nearly double the variance), and with crossover existing for upper-limb coordination and locomotor skill predictor variables only. While gender differences in predictive power favoring females have not been explained previously for these specific relationships, the inclusion of multiple MSP variables when predicting musculoskeletal fitness is in-line with findings from Cantell et al. (2008) and Cattuzzo et al. (2016) who found lower levels of muscular strength and endurance performances in lower motorically skilled children, adolescents, and adults. Overall, without clear patterns of predictor variables that distinguished the gender-specific PF models from each other, the present data do not lend themselves to drawing conclusions that fitness variables are influenced by different predictors for males and females. Instead, the relationships of these MSP, PC, and PF variables simply seem to be stronger for females than males.

Finally, the variance explained for female PA exceeded that of both the male and the full PA models. Perceived athletic competence served as the only significant predictor for the male model, while the female model included PACER, global self-worth, object control, locomotor, and upper-limb coordination. These findings are somewhat similar to what has been observed in younger girls, with measures of MSP, aerobic PF, and PC significantly related to PA (with low to moderate strengths; Khodaverdi et al., 2016). It deserves mention, though, that locomotor scores were negatively related to self-reported PA, and female object control (upper-limb coordination) skills were more predictive of PA in females than in males, which conflicts with what has been reported in previous research (for a review, see Morgan, Okely, Cliff, Jones, Baur, 2008). Therefore, while five predictor variables representing PF, MSP, and PC factors were included in the female PA model, the relative lack of explanatory power (i.e., 19.3%) and lack of consistency with the other models fails to produce robust conclusions. However, as is later discussed, before drawing conclusions about the viability of

maintaining PA as a significant factor for adult iterations of the models proposed by Hands and Larkin (2002) and Stodden et al. (2008), a closer look at the potential influence of the subjective nature of the methods for assessing PA should be explored.

4.4. Implications

With these results in mind, support for what Ennis (2011) termed a “balanced approach” to physical education could be beneficial for individuals’ health across the lifespan. While her work focused primarily in K-12 educational settings, a focus on enhancing fundamental movement skills, self-perceptions of competence, along with a personalized understanding of how physical activity earlier in life can positively impact one’s abilities and motivations to move. However, attention to this development may be particularly critical while children are regularly in structured physical education settings (that align with early “sensitive periods” of development), which are laying the groundwork for lifelong movement capabilities and attitudes about physical activity and one’s self as a mover (Clark, 2005; Hardy et al., 2012). Failing to develop and maintain proficiencies in fundamental motor skills that serve as the foundation for more complex physical activities, exercises, and sports can lead to a decreased range of activity options available and a reduced opportunity to accrue health benefits associated with enhanced fitness.

With more positive assessments of PA, PF, MSP, and PC measures in males, it is apparent that significant intervention to aid in enhancing these capabilities and perceptions with females is still needed to improve their health and well-being. These efforts are likely needed before young adulthood, as others have observed a maintenance or widening of gender-discrepancies (favoring males) in MSP (e.g., Cairney et al., 2017), PA (Caspersen, Pereira, & Curran, 2000), and PF (Kemper, Verschuur, & de Mey, 1989) with time. For example, physical education settings, both in K-12 and college institutions, could use a variety of strategies to achieve these intervention goals. For example, promoting activities as gender-neutral (even those typically considered to be male-dominated) by offering equitable participation opportunities with and using non-gendered language and images when promoting these activities can positively impact perceptions of appropriateness and competence, even in young adults who have experienced more years of aversive socialization (Solmon, Lee, Belcher, Harrison, & Wells, 2003). Additionally, offering curricula that include more gender neutral-activities (e.g., outdoor adventure) or those that tend to draw greater interest from females (e.g., fitness and dance) could promote greater engagement in motor skill practice and development (Lackman & Imperiale-Hagerman, 2014). Finally, utilizing strategies that minimize messages that males are more proficient in these domains than females (e.g., utilizing mixed-gender groups of individuals with similar ability levels and referencing mixed-gender peer/professional models) could positively influence self-competence perceptions and participation.

4.5. Strengths and limitations

The major strength of this study comes from the inclusion of the PF, PA, MSP, and PC variables in the analyses. While previous work has substantiated the existence of relationships among subsets of these factors, very few have utilized this holistic approach which allows for a better understanding of the multiple interactions that exist as well as the explanatory weight each variable brings to the “big picture”. Additionally, the large sample size with a relatively balanced gender distribution allowed for powerful statistical analyses for the whole groups and male and female sub-groups. This opportunity led to some compelling gender discrepancies that warrant further investigation before more definitive recommendations for practice can be made. Finally, the inclusion of the process- and product-oriented assessments of MSP helped demonstrate that both qualitative MSP technique and quantitative MSP outcomes are related to PF and PA. Therefore, both classes of assessments appear to be equally amenable for future investigations, and practitioners may be able to improve related health outcomes by tailoring their efforts to assessing, improving, and reinforcing development observed in motor skills across both sets of criterion.

However, the study is not without its limitations. While the sample was large, it was relatively homogeneous in terms of ethnicity. Additionally, due to the fact all participants were students at the same institution, relative homogeneity can also be assumed along the lines of social economic status and regionally influenced characteristics (e.g., availability of certain PA activities, emphasis on motor skill development in K-12 physical education curriculum). While the sample did represent individuals in young adulthood, the range of ages represented was narrow and restricted to the first few years after adolescence. Replication of these findings among more diverse populations is warranted before the findings can be generalized.

While all models tested offered some support for previously established relationships between MSP, PF, self-reported PA, and PC, only the full curl-up model and female models for cardiovascular PF and curl-up performance included PA as a significant (yet relatively minor) predictor. Additionally, the PA model itself provided less compelling findings due to a smaller percentage of variance explained and fewer predictor variables included as compared to the PF models. With few comparative models investigated to date, future research should examine these potential relationships using more objective PA assessments that pose less risk of error related to self-report biases (e.g., recall errors, self-serving responses; Prince et al., 2008). Doing so would help determine if PA is not strongly and significantly predicted by PF, MSP, and PC in young adulthood or if the present study failed to find existing associations due to problematic subjective measures of PA. Additionally, there would be value in exploring the relationships using instrumentation that has been developed and validated for use with these older populations, particularly those that relate to MSP. Currently, availability of such measures are scarce as their major utility tends to be for physical education settings, which are more focused on physical activity engagement as opposed to basic motor skill development in college-aged populations (Hensley, 2000).

While the present study provides a snapshot of how the PF, PA, MSP, and PC variables relate during early adulthood, these findings do not represent a true investigation of how these factors track longitudinally. Although some research has tracked these relationships across time (e.g., Cantell et al., 2008; Haga, 2009; Haga et al., 2015; Logan et al., 2015), studies have been limited to

childhood and adolescent populations and/or do not consider all potential variables of interest. With added support for these associations substantiated in a young adult population, future research should be conducted to verify if and how these variables track into young adulthood and later life stages. Additionally, the current analyses does not allow for the assumption of causation. To verify the intervention variables that would be most effective in promoting health-related changes, follow-up research should verify the relative strength and directionality of these relationships. This research could further initial works conducted by Barnett, Morgan et al. (2008), Barnett, Van Beurden et al. (2008) who proposed MSP should drive PC, but that PC likely has more direct influence on PA motivation than MSP (providing initial evidence that PC may be the more efficacious intervention target for increased activity).

5. Conclusions

The present study examined associations between motor skill proficiency, perceived self-competence, physical fitness, and physical activity in a college-aged population. Data presented here provide support for these relationships, particularly in the context of cardiovascular fitness, indicating that motor skill proficiency and perceived self-competence both influence cardiovascular fitness levels, although physical activity was only found to be significant for females. Models aimed at predicting muscular strength and endurance also aligned with earlier work done with younger populations, although less variance was explained. Overall, the ability of these variables to predict self-reported physical activity was limited in this sample. And finally, the viability of these variables as meaningful predictors of physical activity and fitness appear to be more meaningful for females than for males. This last finding, in addition to the tendency for male scores to reflect a more encouraging PF, MSP, and PC profile, provides future research and practitioners some insight into where meaningful questions and intervention may be directed. Overall, early intervention in terms of enhancing MSP and PC may be fruitful for promoting future fitness and associated health outcomes, especially in females who appear to remain at greater risk for inactivity, lower fitness, lower motor skill level, and less positive self-perceptions as they relate to their physical characteristics and capabilities into young adulthood.

Funding

This work was funded by a 2013 College of Health and Behavioral Studies Faculty Research and Teaching Grant (James Madison University, US).

Disclosures

The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. There are no known conflicts of interest.

References

- American College of Sports Medicine (2018). *ACSM's guidelines for exercise testing and prescription* (10th ed.). Philadelphia, PA: Wolters Kluwer.
- Babic, M. J., Morgan, P. J., Plotnikoff, R. C., Lonsdale, C., White, R. L., & Lubans, D. R. (2014). Physical activity and physical self-concept in youth: Systematic review and meta-analysis. *Sports Medicine*, 44(11), 1589–1601. <https://doi.org/10.1007/s40279-014-0229-z>.
- Barnett, L. M., Lai, S. K., Veldman, S. L. C., Hardy, L. L., Cliff, D. P., Morgan, P. J., ... Kelly, A. D. (2016). Correlates of gross motor competence in children and adolescents: A systematic review and meta-analysis. *Sports Medicine*, 46(11), 1663–1688. <https://doi.org/10.1007/s40279-016-0495-z>.
- Barnett, L. M., Morgan, P. J., van Beurden, E., & Beard, J. R. (2008). Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: A longitudinal assessment. *International Journal of Behavioral Nutrition and Physical Activity*, 5, 1–12. <https://doi.org/10.1186/1479-5868-5-40>.
- Barnett, L. M., Van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2008). Does childhood motor skill proficiency predict adolescent fitness? *Medicine and Science in Sports and Exercise*, 40(12), 2137–2144. <https://doi.org/10.1249/MSS.0b013e31818160d3>.
- Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health*, 44(3), 252–259. <https://doi.org/10.1016/j.jadohealth.2008.07.004>.
- Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2010). Gender differences in motor skill proficiency from childhood to adolescence: A longitudinal study. *Research Quarterly for Exercise and Sport*, 81(2), 162–170. <https://doi.org/10.1080/02701367.2010.10599663>.
- Beets, M. W., & Pitetti, K. H. (2006). Criterion-referenced reliability and equivalency between the PACER and 1-mile run/walk for high school students. *Journal of Physical Activity and Health*, 3, S21–S33.
- Beets, M. W., Pitetti, K. H., & Cardinal, B. J. (2005). Progressive aerobic cardiovascular endurance run and body mass index among an ethnically diverse sample of 10–15 year olds. *Research Quarterly for Exercise and Sport*, 76, 389–397.
- Bruininks, R., & Bruininks, B. (2005). *Bruininks-Oseretsky test of motor proficiency* (2nd ed.). Minneapolis, MN: NCS Pearson.
- Bürgi, F., Meyer, U., Granacher, U., Schindler, C., Marques-Vidal, P., Kriemler, S., & Puder, J. J. (2011). Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: A cross-sectional and longitudinal study. *International Journal of Obesity*, 35(7), 937–944. <https://doi.org/10.1038/ijo.2011.54>.
- Cairney, J., Hay, J. A., Faght, B. E., & Hawes, R. (2005). Developmental coordination disorder and overweight and obesity in children aged 9–14 y. *International Journal of Obesity*, 29(4), 369–372. <https://doi.org/10.1038/sj.ijo.0802893>.
- Cairney, J., Veldhuizen, S., King-Dowling, S., Faght, B. E., & Hay, J. (2017). Tracking cardiorespiratory fitness and physical activity in children with and without motor coordination problems. *Journal of Science and Medicine in Sport*, 20(4), 380–385. <https://doi.org/10.1016/j.jsams.2016.08.025>.
- Cantell, M., Crawford, S. G., & Doyle-Baker, P. K. (2008). Physical fitness and health indices in children, adolescents and adults with high or low motor competence. *Human Movement Science*, 27(2), 344–362. <https://doi.org/10.1016/j.humov.2008.02.007>.
- Caspersen, C. J., Pereira, M. A., & Curran, K. M. (2000). Changes in physical activity patterns in the United States, by sex and cross-sectional age. Retrieved from *Medicine and Science in Sports and Exercise*, 32(9), 1601–1609. <http://www.msse.org>.
- Cattuzzo, M. T., dos Santos Henrique, R., Hervaldo Nicolai Ré, A., Santos de Oliveira, I., Machado Melo, B., de Sousa Moura, M., ... Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport*, 19, 123–129.
- Clark, J. E. (2005). From the beginning: A developmental perspective on movement and mobility. *Quest*, 57, 37–45.
- Duncan, M. J., Bryant, E., & Stodden, D. (2017). Low fundamental movement skill proficiency is associated with high BMI and body fatness in girls but not boys aged 6–11 years old. *Journal of Sports Sciences*, 35(21), 2135–2141. <https://doi.org/10.1080/02640414.2016.1258483>.
- Eisenmann, J. C., Welk, G. J., Wickel, E. E., & Blair, S. N. (2007). Combined influence of cardiorespiratory fitness and body mass index on cardiovascular disease risk factors

- among 8–18 year old youth: The Aerobics Center Longitudinal Study. *International Journal of Pediatric Obesity*, 2(2), 66–72. <https://doi.org/10.1080/17477160601133713>.
- Gabriel, K. P., McClain, J. J., Schmid, K. K., Storti, K. L., & Ainsworth, B. E. (2011). Reliability and convergent validity of the past-week Modifiable Activity Questionnaire. *Public Health and Nutrition*, 14(3), 435–442.
- Gísladóttir, P., Haga, M., & Sigmundsson, H. (2014). Motor competence and physical fitness in adolescents. *Pediatric Physical Therapy*, 26(1), 69–74. <https://doi.org/10.1097/PEP.0000000000000066>.
- Haga, M. (2009). Physical fitness in children with high motor competence is different from that in children with low motor competence. *Physical Therapy*, 89(10), 1089–1097. <https://doi.org/10.2522/ptj.20090052>.
- Haga, M., Gísladóttir, T., & Sigmundsson, H. (2015). The relationship between motor competence and physical fitness is weaker in the 15–16 yr. adolescent age group than in younger age groups (4–5 yr. and 11–12 yr.). *Perceptual and Motor Skills*, 121(3), 900–912. <https://doi.org/10.2466/10.PMS.121c24x2>.
- Hands, B., & Larkin, D. (2002). Physical fitness and Developmental Coordination Disorder. In S. A. Cermak, & D. Larkin (Eds.). *Developmental Coordination Disorder* (pp. 172–184). New York: Delmar.
- Hands, B., Larkin, D., Parker, H., Straker, L., & Perry, M. (2009). The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Medicine & Science in Sports*, 19(5), 655–663.
- Hands, B., Licari, M., & Piek, J. (2015). A review of five tests to identify motor coordination difficulties in young adults. *Research in Developmental Disabilities*, 41, 40–51. <https://doi.org/10.1016/j.ridd.2015.05.009>.
- Hardy, L. L., Reinten-Reynolds, T., Espinel, P., Zask, A., & Okley, A. D. (2012). Prevalence and correlates of low fundamental movement skill competency in children. *Pediatrics*, 130(2), e390–398.
- Harter, S. (1990). Issues in the assessment of the self-concept of children and adolescents. In A. M. La Greca (Ed.). *Through the eyes of the child: Obtaining self-reports from children and adolescents* (pp. 292–325). Boston, MA: Allyn & Bacon.
- Hensley, L. D. (2000). Current status of basic instruction programs in physical education at American colleges and universities. *Journal of Physical Education, Recreation, and Dance*, 71(9), 30–36.
- Hume, C., Bagley, S., Crawford, D., Salmon, J., Okely, A. D., Telford, A., & Booth, M. (2008). Does weight status influence associations between children's fundamental movement skills and physical activity? *Research Quarterly for Exercise and Sport*, 79(2), 158–165. <https://doi.org/10.1080/02701367.2008.10599479>.
- Issartel, J., McGrane, B., Fletcher, R., O'Brien, W., Powell, D., & Belton, S. (2017). A cross-validation study of the TGMD-2: The case of an adolescent population. *Journal of Science and Medicine in Sport*, 20(5), 475–479. <https://doi.org/10.1016/j.jsams.2016.09.013>.
- Jackson, A. W., Fromme, C., Plitt, H., & Mercer, J. (1994). Reliability and validity of a 1-minute push-up test for young adults. *Research Quarterly for Exercise and Sport*, 65(Suppl.), A57–A58 [Abstract].
- Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, 7, 40–56. <https://doi.org/10.1186/1479-5868-7-40>.
- Jekauc, D., Wagner, M. O., Herrmann, C., Hegazy, K., & Woll, A. (2017). Does physical self-concept mediate the relationship between motor abilities and physical activity in adolescents and young adults? *PLoS One*, 12(1), <https://doi.org/10.1371/journal.pone.0168539>.
- Kemper, H. C. G., Verschuur, R., & de Mey, L. (1989). Longitudinal changes of aerobic fitness in youth ages 12 to 23. *Pediatric Exercise Science*, 1(3), 257–270. <https://doi.org/10.1123/pes.1.3.257>.
- Kim, J., Must, A. G., Fitzmaurice, M., Gillman, M. W., Chomitz, V., Kramer, E., ... Peterson, K. E. (2005). Relationship of physical fitness to prevalence and incidence of overweight among schoolchildren. *Obesity Research*, 13, 1246–1254.
- Kimm, S. Y., Glynn, N. W., Obarzanek, E., Kriska, A. M., Daniels, S. R., Barton, B. A., & Liu, K. (2005). Relation between the changes in physical activity and body-mass index during adolescence: A multicentre longitudinal study. *Lancet*, 366(9482), 301–307. [https://doi.org/10.1016/S0140-6736\(05\)66837-7](https://doi.org/10.1016/S0140-6736(05)66837-7).
- Lackman, J., & Imperiale-Hagerman, S. (2014). A southern university's basic physical education program: Gendered student choices of physical activity. *GAHPERD Journal*, 46(1), 10–13.
- Logan, S. W., Kipling Webster, E., Getchell, N., Pfeiffer, K. A., & Robinson, L. E. (2015). Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: A systematic review. *Kinesiology Review*, 4(4), 416–426. <https://doi.org/10.1123/kr.2013-0012>.
- Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: Review of associated health benefits. *Sports Medicine*, 40(12), 1019–1035. <https://doi.org/10.2165/11536850-000000000-00000>.
- Masciuch, S. W., McRae, L. S. E., & Young, J. D. (1990). The Harter Self-Perception Profile: Some normative and psychometric data. *Psychological Reports*, 67, 1299–1303.
- Meredith, M. D., & Welk, G. J. (2010). *Fitnessgram and activitygram test administration manual* (4th ed.). Champaign, IL: Human Kinetics.
- Morano, M., Colella, D., Robazza, C., Bortoli, L., & Capranica, L. (2011). Physical self-perception and motor performance in normal-weight, overweight and obese children. *Scandinavian Journal of Medicine and Science in Sports*, 21(3), 465–473. <https://doi.org/10.1111/j.1600-0838.2009.01068.x>.
- Morgan, P. J., Okely, A. D., Cliff, D. P., Jones, R. A., & Baur, L. A. (2008). Correlates of objectively measured physical activity in obese children. *Obesity*, 16(12), 2634–2641. <https://doi.org/10.1038/oby.2008.463>.
- Neeman, J., & Harter, S. (1986). *Manual of the self-perception profile for college students*. Denver, CO: University of Denver.
- Okely, A. D., Booth, M., & Patterson, J. W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine and Science in Sports and Exercise*, 33(11), 1899–1904. <https://doi.org/10.1097/00005768-200111000-00015>.
- Papaioannou, A. (1997). Perceptions of motivational climate, perceived competence, and motivation of students of varying age and sport experience. *Perceptual and Motor Skills*, 85(2), 419–430. <https://doi.org/10.2466/pms.1997.85.2.419>.
- Prince, S., Adamo, K., Hamel, M., Hardt, J., Gorber, S., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 5(1), 56. <https://doi.org/10.1186/1479-5868-5-56>.
- Raudsepp, L., Liblik, R., & Hannus, A. (2002). Children's and adolescents' physical self-perceptions as related to moderate to vigorous physical activity and physical fitness. *Pediatric Exercise Science*, 14(1), 97–106. <https://doi.org/10.1123/pes.14.1.97>.
- Robertson, L. D., & Magnusdottir, H. (1987). Evaluation of criteria associated with abdominal fitness testing. *Research Quarterly for Exercise and Sport*, 58, 355–359.
- Robinson, L. E. (2011). The relationship between perceived physical competence and fundamental motor skills in preschool children. *Child: Care, Health and Development*, 37(4), 589–596. <https://doi.org/10.1111/j.1365-2214.2010.01187.x>.
- Ruiz, J. R., Sui, X., Lobelo, F., Lee, D. C., Morrow, J. R., Jackson, A. W., ... Blair, S. N. (2009). Muscular strength and adiposity as predictors of adulthood cancer mortality in men. *Cancer Epidemiology Biomarkers and Prevention*, 18(5), 1468–1476. <https://doi.org/10.1158/1055-9965.EPI-08-1075>.
- Sgro, F., Quinto, A., Pignato, S., & Lipoma, M. (2016). Comparison of product and process oriented model accuracy for assessing counter movement vertical jump motor proficiency in pre-adolescents. *Journal of Physical Education and Sport*, 16(3), 921–926.
- Solmon, M. A., Lee, A. M., Belcher, D., Harrison, L., & Wells, L. (2003). Beliefs about gender appropriateness, ability, and competence in physical activity. *Journal of Teaching in Physical Education*, 22(3), 261–279. <https://doi.org/10.1123/jtpe.22.3.261>.
- Southall, J. E., Okley, A. D., & Steele, J. R. (2004). Actual and perceived physical competence in overweight and nonoverweight children. *Pediatric Exercise Science*, 16(1), 15–24.
- Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Robertson, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest*, 60(2), 290–306. <https://doi.org/10.1080/00336297.2008.10483582>.
- Stodden, D. F., Langendorfer, S. J., & Robertson, M. A. (2009). The association between motor skill competence and physical fitness in young adults. *Research Quarterly for Exercise and Sport*, 80(2), 223–229. <https://doi.org/10.1080/02701367.2009.10599556>.
- Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise*, 40(1), 181–188. <https://doi.org/10.1249/mss.0b013e31815a51b3>.
- Ulrich, D. (2000). *Test of gross motor development-2* (2nd ed.). Austin, TX: ProEd Inc.
- Vedul-Kjelsås, V., Sigmundsson, H., Stensdotter, A. K., & Haga, M. (2012). The relationship between motor competence, physical fitness and self-perception in children. *Child: Care, Health and Development*, 38(3), 394–402. <https://doi.org/10.1111/j.1365-2214.2011.01275.x>.
- Welk, G. J., & Eklund, B. (2005). Validation of the children and youth physical self perceptions profile for young children. *Psychology of Sport and Exercise*, 6(1), 51–65. <https://doi.org/10.1016/j.psychsport.2003.10.006>.
- Wrotniak, B. H., Epstein, L. H., Dorti, J. M., Jones, K. E., & Kondilis, V. A. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics*, 118, 1758–1765.