The Physical Educator Vol. 70 • pp 155-186 • 2013

PEDAGOGY

Effects of Interventions Based in Behavior Analysis on Motor Skill Acquisition: A Meta-Analysis

Andrew E. Alstot, Minsoo Kang, Crystal D. Alstot

Abstract

Techniques based in applied behavior analysis (ABA) have been shown to be useful across a variety of settings to improve numerous behaviors. Specifically within physical activity settings, several studies have examined the effect of interventions based in ABA on a variety of motor skills, but the overall effects of these interventions are unknown. Therefore, the purposes of the study were to use meta-analysis techniques to examine the effect of ABA-based interventions on motor skill acquisition in physical education and sport settings and to identify whether moderating variables influenced the overall effect. A search of electronic databases as well as a manual search of reference lists was conducted to identify studies that utilized ABA-based interventions in physical activity settings to improve motor skills. Studies that were conducted using single-subject design, used a behavioral intervention, and included a dependent variable that measured correct and incorrect trials of a motor skill were selected for inclusion in the meta-analysis. From the 22 studies that fit the inclusion criteria, necessary data were extracted and 188 effect sizes (ES) were calculated using the odds ratio formula. Moderator analyses on gender, age, ABA principle(s) used in the intervention, setting, and type of skill were also conducted. The overall ES log

Andrew E. Alstot is an assistant professor, Department of Exercise Science, Pacific University. Minsoo Kang is an associate professor, Department of Health and Human Performance, Middle Tennessee State University. Crystal D. Alstot is an instructor, Department of Psychology, Kaplan University. Please send author correspondence to aalstot@pacificu.edu

odds ratio (ESLOR) was 1.49, indicating ABA interventions had a large effect on participants' skill acquisition. Additionally, it was found all five moderator variables influenced the impact of the behavioral interventions on motor skills. Practitioners should note ABA-based instructional methods can positively influence the motor skill acquisition of their students and athletes.

Students' motor skill development is an essential component of any physical educator's job. Standard 1 of the National Standards for Physical Education states a physically educated person "demonstrates competency in motor skills and movement patterns needed to perform a variety of physical activities" (National Association for Sport and Physical Education, 2004, p. 11). Additionally, Hands (2008) found children with high motor competence performed better on measures of physical fitness than children with low motor skill, and Barnett, Van Beurden, Morgan, Brooks, and Beard (2008) discovered children with high object control skill proficiency are more likely to become physically fit as adolescents than those with low proficiency. Likewise, Stodden, Langendorfer, and Roberton (2009) found 79% of the variance in young adults' physical fitness was accounted for by three motor skills (i.e., jumping, throwing, and kicking), suggesting health-related physical fitness is highly related to motor skill competence. These studies provide empirical evidence and a solid rationale for physical activity practitioners who work with child and adult populations to focus on motor skill acquisition in their instruction. Furthermore, sport coaches are interested in improving their athletes' motor skills as well. A high rate of success is of great importance to the effectiveness of athletes who practice motor skills extensively to achieve efficiency in their sport-specific skills. Therefore, teaching techniques that aid in the development and improvement of motor skills are of high value to physical education teachers, coaches, and other physical activity practitioners.

Researchers have found a variety of factors contribute to an improvement in motor skill development in physical education. For example, several seminal studies in physical education showed positive relationships between correctly performed practice trials and student achievement (Ashy, Lee, & Landin, 1988; Buck, Harrison, & Bryce, 1990; Silverman, 1985). More recently, Silverman (2011) suggested as teachers optimize students' practice within physical education, students' achievement is subsequently maximized.

Similarly, Rink (2003) stated students achieve at a higher level when more practice time is allowed, especially when their practice trials are performed with a high degree of success. Despite the repeated endorsement of practice within the literature, several variables were identified that could potentially influence these practice effects on motor skill acquisition. Thomas and French (1985) identified gender and age differences when participants completed several motor tasks. Donahue, Gillis, and King's (1980) review suggested reinforcement-based interventions as well as public postings were effective means of improving motor skills, but did not necessarily endorse any other specific category of intervention. Additionally, Lee (1993) suggested the setting in which the intervention is introduced as well as the skill targeted could influence the effectiveness of the intervention. Therefore, students' gender and age, as well as the type of intervention used, the setting in which the skill is taught, and the type of skill being taught may also influence the practice effects. Nevertheless, regardless of the students, setting, or intervention type, the literature consistently reveals the importance of optimal practice within physical education settings.

Interventions based in applied behavior analysis, which has its foundations in psychology, have been extensively implemented to increase the quality of practice as well as athletes' and students' success rate in performing motor skills (Donahue et al., 1980; Lee, 1993; Ward & Barrett, 2002). Behaviorism, the theoretical framework from which behavior analysis is derived, is based on the premise that human behaviors (e.g., motor skills) can be changed by manipulating the stimuli immediately preceding and/or immediately following the occurrence of a target behavior (Cooper, Heron, & Heward, 2007). For example, specifically within physical activity settings, practitioners can alter the stimuli preceding a behavior (e.g., giving instructional cues) and after the occurrence of the behavior (e.g., reinforcement through verbal praise or tangible reward). By altering these stimuli, one could predict the probability of the behavior occurring again based on these environmental manipulations (Cooper et al., 2007).

The history of the application of behavior analytic principles (e.g., cues, reinforcement, punishment) in general education settings is well documented; behavioral techniques have been extensively implemented in classroom educational settings in an attempt to reduce problem behaviors (Harris & Sherman, 1973; Lalli, Browder, Mace, & Brown, 1993), increase student achievement (Fueyo &

Bushell, 1998; Miller & Kelley, 1994), and increase the efficacy of teachers' instruction (Ingham & Greer, 1992). Walberg (1984) conducted a meta-analysis of the effects of teacher and instructional methods on student academic achievement, which revealed behavioral principles (i.e., reinforcement, cues, and feedback) had a large impact on achievement.

In the early 1970s, applied behavior analysis was expanded from psychology and general education settings to physical education and sport arenas when Siedentop and Rushall (1972) proposed a model for applying behavior analysis-based strategies to the acquisition of motor skills. From that point, behavior analysis became a frequently tested model among physical education and sport researchers (see reviews by Donahue et al., 1980; Lee, 1993; Ward & Barrett, 2002). Subsequently, in their review of behavior analysis research, Ward and Barrett (2002) identified four categories of behavioral research applied within a physical education setting: (a) teacher training interventions, (b) class and behavior management interventions, (c) instruction and/or student learning interventions, and (d) interventions with students with disabilities. Although behavioral interventions have been shown to be useful across several categories of behaviors pertinent to physical activity practitioners, the current study focuses on Ward and Barrett's third category—instruction and/or student learning—to systematically examine the use of behavioral strategies intended to improve motor skills in physical activity settings.

As mentioned previously, behavior analytic interventions have been used in sport and physical education settings in an attempt to improve motor skills. However, the overall effect of these interventions is not known; thus, a meta-analysis of behavioral interventions can provide the magnitude of the effects (Lipsey & Wilson, 2001) of these interventions on motor skills in athletic and educational settings. Therefore, the initial purpose of the study was to use meta-analysis techniques to determine the effectiveness of using behavior analytic interventions in physical education, sport, and other physical activity settings to improve motor skills.

In addition to examining the overall effect of behavior analysis techniques on motor skills, meta-analyses can also be used to examine whether other variables influence the impact of the interventions. Several potential moderating variables (i.e., variables that possibly influenced the overall effectiveness of the behavioral interventions) were identified in the literature (Donahue et al., 1980;

Lee, 1993; Thomas & French, 1985). Thus, the secondary purpose of the study was to identify whether the moderating variables of gender, age, type of behavioral intervention used, setting, and/or skill influenced the effect of the interventions. The subcategories of each moderating variable were defined as follows: Participants' gender was categorized as male, female, or both (i.e., studies that instructed mixed-gender groups), and age was divided into elementary, secondary, or college/adult aged. The type of behavioral intervention used was categorized as reinforcement, peer interventions, public posting, goal setting, or other, such as behavioral coaching, form training, prompting, and self-recording. The setting in which the intervention was administered was coded as physical education, integrated physical education (i.e., classes in which special needs students are integrated into instruction with typically developing peers), sport, or other physical activity setting (e.g., dance classes or summer camps). Finally, the motor skill being taught was classified as a basketball, volleyball, football, tennis, or other (swimming, speed skating, ballet, soccer, etc.) skill. Each of the moderator variables were divided into subcategories based on the amount of data available in the identified studies. For example, several studies utilized a reinforcement-based intervention so that "reinforcement" was given its own subcategory. However, numerous studies utilized a behavioral intervention that was not included in any additional studies. These were all included in the *other* category because not enough data were available for that individual category to stand alone. The division of the *other* subcategories for the additional moderator variables (i.e., setting and skill) followed the same protocols.

Method

The methodology used in the current study was designed following general protocols for conducting meta-analyses as described by Lipsey and Wilson (2001). Included in the following method section is a description of how previously published behavior analysis in physical activity settings research was identified, how studies were selected for inclusion in the meta-analysis from the pool of identified studies, how data were extracted from the included studies, and how those data were analyzed to assess the effects of behavioral interventions.

Data Sources

An electronic search for studies was conducted utilizing the following online databases: WilsonWeb, ProQuest, Google Scholar, PsycINFO, Academic Search Premier, and Oregon PDF in Health and Performance. As suggested by Lipsey and Wilson (2001), a list of keywords "that broadly cover the relevant domain" (p. 26) should be utilized to search the included databases. The keywords identified by the authors that covered the domain of behavior analysis interventions in physical activity settings and used in the query, searched in one or more combinations, were *behavior analysis, behavior modification, behavioral, physical education, sport/sports, athlete/athletic*, and *motor skills*. In addition to the database searches, keywords were used to search the websites of the following known behavior analysis journals: *Journal of Applied Behavior Analysis*; *Behavior Modification*; *Journal of Behavior Analysis in Health, Sports, Fitness, and Medicine*; and *Journal of Behavioral Education*. In addition, once studies were identified via electronic search, their reference lists were then inspected to examine for additional studies that may fit into the current meta-analysis (Lipsey & Wilson, 2001). The search was limited to English language publications and included journal articles, doctoral dissertations, and master's theses from the year 1975 and later. Dissertations and theses were compared against the identified published articles, thus ensuring the same data set was not included in the analysis twice.

Study Selection

Forty-nine published articles and three dissertations were identified. To be included in the meta-analysis, the study must have had the following characteristics: used a single-subject design (all behavior analysis research utilizes single-subject design; Kennedy, 2005), included a behavior analysis-based intervention (i.e., an intervention that systematically manipulated environmental antecedents and/or consequences subsequent to the occurrences of the behavior), and included a dependent variable that was measured by the number of correct and incorrect trials (of a motor skill) or a percentage representing the number of correct and incorrect trials.

Only studies meeting the inclusion criteria were included in the study. The main reason for exclusion was the lack of a dependent variable that was measured by the number of correct and incorrect trials of a motor skill. For example, McKenzie and Rushall (1974) implemented a behavioral intervention to improve swimming performance as measured by the number of laps swam. The dependent variable in this study did not measure correct or incorrect trials of a swimming skill, but rather the total number of laps the participants completed; therefore, it was not included in the current meta-analysis.

Data Extraction

Following Lipsey and Wilson's (2001) meta-analysis protocols, when studies were identified for inclusion, the first author coded the studies by identifying and recording the following moderating variables for each study: gender and age group of the participants, behavioral principle used in the intervention (e.g., reinforcement-based intervention, goal setting, public posting), the setting of the intervention (e.g., physical education, athletics, other physical activity setting), and the motor skill measured (e.g., football skill, basketball skill, tennis skill). Lipsey and Wilson suggested conducting a reliability check of the coding process. Therefore, an additional author independently coded 30% of the included studies. Disagreements were resolved by consensus among the coders.

Additionally, several effect sizes (ES) were calculated for each study following guidelines described by Lipsey and Wilson (2001); calculation of the ES statistic provides a quantitative measure of the magnitude of the effect of the intervention on the dependent variable (Christensen, 2007). Because of the nature of behavior analysis research (i.e., single-subject design that uses each individual to serve as its own control), individual participants served as both the control group and the treatment group for the calculation of each ES. Several single-subject design variations were present in the included studies. For simple single-subject and multiple baseline designs, the data presented during baseline phase (A) served as the control group for ES calculation purposes and the intervention phase (B) served as the treatment group. For studies that utilized a reversal design (i.e., ABAB), the following criteria were used to extract the desired data for ES calculation: Two ESs were calculated for each participant, and an ES was computed for each phase of the study (i.e., each "AB" phase). In an ABAC design, two ESs were also calculated for each participant: one for the "AB" phase and one for the "AC" phase. One study used an ABACABC design. Three ESs were calculated for each participant: one for "AB," one for "AC," and one for "ABC".

For studies that utilize single-subject design, methods for calculating ESs are typically computed using one of four methods: mean baseline reduction, percentage of nonoverlapping data, percentage of zero data, or the regression-based *d* statistic (Campbell, 2004). However, these methods were not appropriate for calculation of ES statistics based on the necessary data extracted within the current study. Therefore, ESs were calculated using the odds ratio formula (Lipsey & Wilson, 2001). Subsequently, no other meta-analyses were identified that used the odds ratio formula to calculate ESs with single-subject design studies. Thus, the authors had to take minor liberties within the confines of the odds ratio formula (Lipsey & Wilson, 2001) when calculating ESs for the current study. The odds ratio formula utilizes control and treatment group successes and failures to calculate each ES (Lipsey & Wilson, 2001). The amounts of treatment group (i.e., individual participants' intervention phase/s) and control group (i.e., individual participants' baseline phase/s) successes and failures (e.g., the number of basketball free throws made and missed for each phase of the study) were extracted and used to calculate the ES. If only percentages (i.e., success rate) were reported, 100 total trials were used to approximate the number of correct and incorrect trials (e.g., if a success rate of 82% was reported, it was evaluated as 82 correct trials and 18 incorrect trials). The natural log (ln) of the ES was calculated for each study; the corresponding ES log odds ratio (ESLOR) was recorded. The mean ES was adjusted for sample size (i.e., total number of trials for the individual participants in single-subject design). The first author calculated all included ESs. Lipsey and Wilson (2001) suggested conducting a reliability check of ES calculations. Therefore, an additional author independently calculated a random 30% of the included ESs; agreement was 100%.

Data Analysis

A random effects model (Lipsey & Wilson, 2001) was used to calculate the mean ESLOR and the 95% confidence interval (CI). Weighted mean ES was calculated taking into account the inverse variance of each study's ES. According to Lipsey and Wilson (2001), a log odds ratio ES can be rescaled by dividing 1.83 to make it directly comparable to a standardized mean difference ES. Rescaled ESs can then be evaluated based on Cohen's (1988) definition of ESs: "0.2 = small," "0.5 = medium," and "0.8 = large." This means that if an ES is "large," then the behavioral intervention had a strong impact on the target behavior. Conversely, if an ES is "small," then the intervention had little or no effect on the target behavior.

Homogeneity of the mean ES was evaluated using the Q statistic, which indicates whether all of the ESs are estimating the same population mean ES. In a homogenous distribution, the variability of ESs around their mean is explained by sampling error. In the current study, if the Q statistic was found to be statistically significant ($p < .05$), homogeneity of the ES was to be rejected. If this occurred, it would indicate the variability in ESs is systematic, which is derived from identifiable differences among ESs. Therefore, subsequent moderator analyses were to be conducted using the methods described by Lipsey and Wilson (2001) to examine the extent to which moderator variables (i.e., gender, age, type of intervention, setting, and skill) influenced the overall effect of behavioral interventions on motor skill acquisition. The Q statistic, however, does not report the extent of heterogeneity. Therefore, the I^2 statistic was calculated, which quantifies the degree of heterogeneity. According to Higgins, Thompson, Deeks, and Altman (2003), I^2 values of 25%, 50%, and 75% would be considered low, moderate, and high levels of heterogeneity, respectively. SPSS 16 was used to conduct moderator analyses.

Results

Search Results

Forty-nine published articles and three dissertations were found. Thirty studies were excluded from the meta-analysis due to not meeting the inclusion criteria or insufficient data in the article whereby an ES could not be calculated. As a result, 22 studies (i.e., 20 journal articles and two doctoral dissertations) fit the inclusion criteria and were included in the meta-analysis.

Overall Effect Size

The ESLORs for each study are provided in Table 1. From the 22 studies included in the meta-analysis, 188 ESLORs were calculated. At least one ES was calculated for each included study. Because studies utilizing single-subject design typically include more than one participant, multiple ESs were extracted from individual studies, one or more from each included subject. A random effects model (Lipsey & Wilson, 2001) was used, and the weighted mean ESLOR was 1.49, 95% CI [1.34, 1.75]. The rescaled ES was 0.81, indicating

Table 1

Characteristics of the Studies Included in the Meta-Analysis of Behavior Analytic Interventions

Study	Gender	Age	Bx Intervention	Setting	Skill	ESLOR
Allison et al. (1980)	male	Elementary	package	sport	Football	2.31
Allison et al. (1980)	male	College	package	physical education	Tennis	5.21
Allison et al. (1980)	male	College	package	physical education	Tennis	3.03
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	1.51
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	2.39
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	2.08
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	0.57
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	1.63
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	0.89
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	3.21
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	1.57
Buzas et al. (1981)	female	Secondary	reinforcement	physical education	Tennis	2.09
Crouch et al. (1997)	both	Elementary	peer intervention	physical education	Volleyball	0.00
Crouch et al. (1997)	both	Elementary	peer intervention	physical education	Volleyball	0.69
Crouch et al. (1997)	both	Elementary	peer intervention	physical education	Volleyball	0.04
Crouch et al. (1997)	both	Elementary	peer intervention	physical education	Volleyball	0.36
Fitterling et al. (1983)	female	Elementary	other	other	Other	3.09
Fitterling et al. (1983)	female	Elementary	other	other	Other	2.44
Fitterling et al. (1983)	female	Elementary	other	other	Other	5.23
Fitterling et al. (1983)	female	Elementary	other	other	Other	3.49

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES_{LOR}
Fitterling et al. (1983)	female	Elementary	other	other	Other	4.05
Fitterling et al. (1983)	female	Elementary	other	other	Other	2.25
Grant et al. (1990)	both	Secondary	other	physical education	Volleyball	-0.51
Grant et al. (1990)	both	Secondary	other	physical education	Volleyball	0.71
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	1.58
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	2.82
Houston-Wilson et al. (1997)	female	Elementary	peer intervention	integrated PE	Other	-0.31
Houston-Wilson et al. (1997)	female	Elementary	peer intervention	integrated PE	Other	0.40
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	0.21
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	1.94
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	1.67
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	1.68
Houston-Wilson et al. (1997)	male	Elementary	peer intervention	integrated PE	Other	1.03
Hupp et al. (1999)	male	Elementary	other	other	Basketball	0.06
Hupp et al. (1999)	male	Elementary	reinforcement	other	Basketball	-1.20
Hupp et al. (1999)	male	Elementary	other	other	Basketball	1.79
Hupp et al. (1999)	male	Elementary	reinforcement	other	Basketball	2.54
Hupp et al. (1999)	male	Elementary	other	other	Basketball	-0.34
Hupp et al. (1999)	male	Elementary	reinforcement	other	Basketball	0.71
Hupp et al. (1999)	male	Elementary	other	other	Basketball	0.43
Hupp et al. (1999)	male	Elementary	reinforcement	other	Basketball	5.25
Hupp et al. (1999)	male	Elementary	reinforcement	other	Basketball	-0.82

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ESLOR
Hupp et al (1999)	male	Elementary	reinforcement	other	Basketball	5.17
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.52
Johnson et al. (2001)	male	Elementary	peer intervention	physical education	Other	2.14
Johnson et al. (2001)	male	Elementary	peer intervention	physical education	Other	1.82
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.27
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.11
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.77
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.40
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	2.41
Johnson et al. (2001)	female	Elementary	peer intervention	physical education	Other	3.25
Johnson et al. (2001)	male	Elementary	peer intervention	physical education	Other	1.43
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	0.64
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	7.08
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	0.69
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	7.67
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	0.73
Kladopoulos et al. (2001)	female	College	other	sport	Basketball	14.09
Komaki et al. (1977)	male	Elementary	package	sport	Football	1.00
Komaki et al. (1977)	male	Elementary	package	sport	Football	1.34
Komaki et al. (1977)	male	Elementary	package	sport	Football	0.74
Melody (1990)	male	College	other	sport	Basketball	1.34
Melody (1990)	male	College	other	sport	Basketball	0.57

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ESLOR
Melody (1990)	male	College	other	sport	Basketball	1.42
Melody (1990)	male	College	other	sport	Basketball	0.92
Melody (1990)	male	College	other	sport	Basketball	1.92
Melody (1990)	male	College	other	sport	Basketball	0.32
Melody (1990)	female	College	other	sport	Basketball	1.70
Melody (1990)	female	College	other	sport	Basketball	0.50
Melody (1990)	female	College	other	sport	Basketball	0.37
Melody (1990)	female	College	other	sport	Basketball	0.50
Rush et al. (1984)	male	Elementary	other	sport	Other	1.18
Rush et al. (1984)	male	Elementary	other	sport	Other	3.22
Rush et al. (1984)	male	Elementary	other	sport	Other	1.72
Rush et al. (1984)	male	Elementary	other	sport	Other	2.30
Rush et al. (1984)	male	Elementary	other	sport	Other	3.25
Rush et al. (1984)	male	Elementary	other	sport	Other	1.25
Rush et al. (1984)	male	Elementary	other	sport	Other	2.03
Rush et al. (1984)	male	Elementary	other	sport	Other	6.29
Rush et al. (1984)	male	Elementary	other	sport	Other	-0.44
Shapiro et al. (1985)	female	Secondary	other	sport	Other	5.54
Shapiro et al. (1985)	female	Secondary	other	sport	Other	2.77
Shapiro et al. (1985)	female	Secondary	other	sport	Other	4.52
Shapiro et al. (1985)	female	Secondary	other	sport	Other	5.22
Shapiro et al. (1985)	male	Secondary	other	sport	Other	5.09

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES_{LOR}
Shapiro et al (1985)	male	Secondary	other	sport	Other	5.06
Smith et al. (2006)	male	College	public posting	sport	Football	1.72
Smith et al. (2006)	male	College	goal setting	sport	Football	2.43
Smith et al. (2006)	male	College	package	sport	Football	5.30
Smith et al. (2006)	male	College	public posting	sport	Football	2.14
Smith et al. (2006)	male	College	goal setting	sport	Football	2.11
Smith et al. (2006)	male	College	package	sport	Football	3.40
Smith et al. (2006)	male	College	public posting	sport	Football	1.56
Smith et al. (2006)	male	College	goal setting	sport	Football	2.63
Smith et al. (2006)	male	College	package	sport	Football	5.30
Smith et al. (2006)	male	College	public posting	sport	Football	1.12
Smith et al. (2006)	male	College	goal setting	sport	Football	1.67
Smith et al. (2006)	male	College	package	sport	Football	2.15
Smith et al. (2006)	male	College	public posting	sport	Football	1.13
Smith et al. (2006)	male	College	goal setting	sport	Football	2.82
Smith et al. (2006)	male	College	package	sport	Football	5.30
Smith et al. (2006)	male	College	public posting	sport	Football	2.17
Smith et al. (2006)	male	College	goal setting	sport	Football	1.51
Smith et al. (2006)	male	College	package	sport	Football	2.98
Smith et al. (2006)	male	College	public posting	sport	Football	0.46
Smith et al. (2006)	male	College	goal setting	sport	Football	1.07
Smith et al. (2006)	male	College	package	sport	Football	2.65

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES_{LOR}
Smith et al. (2006)	male	College	public posting	sport	Football	1.60
Smith et al. (2006)	male	College	goal setting	sport	Football	1.92
Smith et al. (2006)	male	College	package	sport	Football	3.18
Smith et al. (2006)	male	College	public posting	sport	Football	2.17
Smith et al. (2006)	male	College	goal setting	sport	Football	1.51
Smith et al. (2006)	male	College	package	sport	Football	2.98
Wanlin et al. (1997)	female	Secondary	goal setting	sport	Other	1.21
Wanlin et al. (1997)	female	Secondary	goal setting	sport	Other	5.25
Wanlin et al. (1997)	female	Secondary	goal setting	sport	Other	2.78
Ward et al. (1997)	male	College	other	sport	Football	2.29
Ward et al. (1997)	male	College	other	sport	Football	1.65
Ward et al. (1997)	male	College	other	sport	Football	1.41
Ward et al. (1997)	male	College	other	sport	Football	1.62
Ward et al. (1997)	male	College	other	sport	Football	1.61
Ward et al. (1997)	male	College	other	sport	Football	2.42
Ward et al. (1997)	male	College	other	sport	Football	1.93
Ward et al. (1997)	male	College	other	sport	Football	5.06
Ward et al. (1997)	male	College	other	sport	Football	2.07
Ward et al. (1997)	male	College	other	sport	Football	1.65
Ward et al. (1997)	male	College	other	sport	Football	1.71
Ward et al. (1997)	male	College	other	sport	Football	0.45
Ward et al. (1997)	male	College	other	sport	Football	2.25

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES$_{LOR}$
Ward et al (1997)	male	College	other	sport	Football	1.10
Ward et al. (1997)	male	College	other	sport	Football	1.09
Ward et al. (1997)	male	College	other	sport	Football	2.32
Ward et al. (1997)	male	College	other	sport	Football	2.31
Ward et al. (1997)	male	College	other	sport	Football	1.73
Ward et al. (1997)	male	College	other	sport	Football	1.79
Ward et al. (1997)	male	College	other	sport	Football	1.63
Ward et al. (1998) (a)	male	Elementary	peer intervention	physical education	Volleyball	-0.04
Ward et al. (1998) (a)	male	Elementary	peer intervention	physical education	Volleyball	0.73
Ward et al. (1998) (a)	male	Elementary	peer intervention	physical education	Volleyball	-0.23
Ward et al. (1998) (a)	male	Elementary	peer intervention	physical education	Volleyball	0.91
Ward et al. (1998) (a)	female	Elementary	peer intervention	physical education	Volleyball	0.00
Ward et al. (1998) (a)	female	Elementary	peer intervention	physical education	Volleyball	1.91
Ward et al. (1998) (a)	female	Elementary	peer intervention	physical education	Volleyball	0.65
Ward et al. (1998) (a)	female	Elementary	peer intervention	physical education	Volleyball	-0.23
Ward et al. (1998) (b)	male	Elementary	peer intervention	physical education	Basketball	2.37
Ward et al. (1998) (b)	male	Elementary	peer intervention	physical education	Basketball	3.24
Ward et al. (1998) (b)	male	Elementary	peer intervention	physical education	Basketball	0.22
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	2.83
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	5.23
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	2.84
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	-4.31

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES_{LOR}
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	0.26
Ward et al. (1998) (b)	female	Elementary	peer intervention	physical education	Basketball	-2.99
Ward et al. (2002)	male	College	package	sport	Football	1.99
Ward et al. (2002)	male	College	package	sport	Football	1.72
Ward et al. (2002)	male	College	package	sport	Football	1.60
Ward et al. (2002)	male	College	package	sport	Football	1.80
Ward et al. (2002)	male	College	package	sport	Football	2.05
Ward et al. (2002)	male	College	package	sport	Football	2.06
Ward et al. (2002)	male	College	package	sport	Football	1.57
Ward et al. (2002)	male	College	package	sport	Football	1.79
Ward et al. (2002)	male	College	package	sport	Football	1.93
Ward et al. (2002)	male	College	package	sport	Football	1.63
Ward et al. (2002)	male	College	package	sport	Football	1.72
Ward et al. (2002)	male	College	package	sport	Football	1.53
Ward et al. (2002)	male	College	package	sport	Football	1.48
Ward et al. (2002)	male	College	package	sport	Football	1.79
Ward et al. (2002)	male	College	package	sport	Football	1.56
Wilson (1988)	female	Secondary	package	sport	Basketball	-0.32
Wilson (1988)	female	Secondary	package	sport	Basketball	0.33
Wilson (1988)	female	Secondary	package	sport	Basketball	0.16
Wolko et al. (1993)	female	Elementary	other	sport	Other	-0.22
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.14

Table 1 (cont.)

Study	Gender	Age	Bx Intervention	Setting	Skill	ES_{LOR}
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.04
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.67
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.10
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.15
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.10
Wolko et al. (1993)	female	Elementary	other	sport	Other	-0.09
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.85
Wolko et al. (1993)	female	Elementary	other	sport	Other	0.14
Ziegler (1987)	both	College	other	physical education	Tennis	1.86
Ziegler (1987)	both	College	other	physical education	Tennis	2.13
Ziegler (1987)	both	College	other	physical education	Tennis	1.85
Ziegler (1987)	both	College	other	physical education	Tennis	2.66
Ziegler (1987)	both	College	other	physical education	Tennis	2.08
Ziegler (1987)	both	College	other	physical education	Tennis	2.16
Overall						1.49

Note. Bx Intervention = behavioral principle used in the intervention.

behavior analytic interventions have a large positive effect on the acquisition of motor skills.

Moderator Analysis

The mean ES was heterogeneous (Q = 1,235.62, *df* = 187, *p* < .001, I^2 = 85.87%). I^2 value of 86% indicated a high level of heterogeneity. Subsequent moderator analyses were conducted based on protocols established by Lipsey and Wilson (2001). All five moderator variables were found to influence the overall weighted mean ES: gender (three groups: male, female, and both), Qbetween (Qb) = 14.87, *df* = 2, *p* < .001; age (three groups: elementary, secondary, and college/adult), Qb = 32.14, *df* = 2, *p* < .001; behavioral principle used in the intervention (six groups: package, reinforcement, peer intervention, public posting, goal setting, and other), Qb = 57.77, *df* = 5, *p* <.001; setting (four groups: mainstream physical education, integrated physical education, sport, and other), Qb = 89.50, *df* = 3, *p* < .001; and skill (five groups: football, volleyball, tennis, basketball, and other skills), Qb = 346.05, *df* = 4, *p* < .001. Table 2 describes the mean ES_{LOR} and 95% CI for each of the categories of each of the moderator variables.

Table 2

Effect Sizes by Moderators in the Meta-Analysis of Behavior Analytic Interventions

Moderator Variables	*N*	Moderator Groups	Mean	95% CI	
			ES_{LOR}	From	To
Gender	112	Male	1.57	1.38	1.80
	64	Female	1.41	1.14	1.68
	12	Both	1.14	0.57	1.71
Age group	79	Elementary	1.18	0.94	1.42
	23	Secondary	1.40	0.93	1.88
	86	College/Adult	1.84	1.58	2.05
Behavioral principle used in intervention	33	Package	1.78	1.41	2.15
	15	Reinforcement	1.37	0.84	1.91
	40	Peer intervention	1.31	0.98	1.63
	9	Public posting	1.51	0.79	2.23
	12	Goal setting	1.90	1.18	2.61
	79	Other	1.45	1.20	1.70

Table 2 (cont.)

Moderator Variables	*N*	Moderator Groups	Mean ES_LOR	95% CI From	95% CI To
Setting	50	Mainstream PE	1.55	1.27	1.83
	9	Integrated PE	1.19	0.54	1.84
	113	Sport	1.51	1.31	1.72
	16	Other	1.28	0.73	1.84
Skill	66	Football	1.76	1.52	1.99
	14	Volleyball	0.35	-0.09	0.79
	17	Tennis	2.06	1.65	2.48
	38	Basketball	1.02	0.70	1.34
	53	Other	1.57	1.30	1.83

Note. N = number of effect sizes; CI = confidence interval.

Discussion

The main purpose of the current study was to use meta-analysis techniques to determine the strength of the effect of behavior analytic interventions on the acquisition of motor skills in physical education, sport, and other physical activity settings. The results indicate the use of behavioral principles has a large, positive effect on the acquisition of motor skills. This suggests when teachers, coaches, and other physical activity professionals utilize the principles of applied behavior analysis (i.e., reinforcement and punishment) in a systematic way when instructing their pupils, motor skill acquisition is likely to improve.

Several behavior analysis-based teaching techniques were described in the literature. Smith and Ward (2006) used a public posting intervention to improve motor performance that consists of posting a student's name on an "achievement" board when he or she accomplishes something of significance. The teacher determines as what is considered significant. For example, a teacher might inform the class that anyone who makes 10 baskets will get their name on the board. Then, when names are posted, this public recognition serves as a social reinforcer by drawing positive attention to those who achieved at a high level. Teachers can also personalize the system by having different criteria for students of varying skill level. That way, both low- and high-skilled students will be challenged at appropriate levels and reinforced when each performs at the prescribed level. Additionally, further reinforcement, such as tangible reinforcers (stickers, yo-yos, etc.) or intangible reinforcers (line leader privileges, free choice time, etc.), can be added to the public posting to provide extra incentive for high achievement. Then, students can receive both social and tangible reinforcement for appropriate motor behavior.

Specific reinforcement-based interventions are also commonplace in behavioral literature (Buzas & Ayllon, 1981; Hupp & Reitman, 1999). One of these methods, differential reinforcement, distinguishes between correct performance of a skill (or part of a skill) and incorrect performance to administer social reinforcement. The teacher observes the learner perform a practice trial. If the trial is performed correctly, the teacher reinforces the behavior (i.e., correct skill performance) with a social reinforcer, such as a praise statement. However, if the skill is not performed correctly, the teacher will not say anything to the student. The student only receives reinforcement for correctly performed skill performance. Likewise, teachers can also differentially reinforce individual components of skill performance. If a singular component is performed correctly, the teacher can reinforce only that component and ignores incorrect execution of the other components of the skill. Students receive reinforcement only when skills are performed with correct technique.

Several studies used student-peers to administer reinforcement (Crouch, Ward, & Patrick, 1997; Houston-Wilson, Dunn, van der Mars, & McCubbin, 1997; Johnson & Ward, 2001; Ward, Crouch, & Patrick, 1998). Peers are trained to accurately perform an assessment of each other's skill performance (i.e., process- or product-based assessment). Teachers can set a criteria level for acceptable performance (i.e., a level at which students must perform to receive the reinforcement). Then, based on the results of the assessment, students receive a reinforcer (access to a preferred activity, tangible reinforcers, etc.). With this method, every student has the potential to receive reinforcement (social, via the peer assessment, and tangible, based on the results of the assessment) without much interaction with the teacher. In other words, because the teacher cannot constantly give reinforcement to everyone in class, peer-based interventions can be a feasible alternative in which all students can receive attention, feedback, and reinforcement.

The results of the current meta-analysis indicate the behavioral teaching techniques can be effective in improving students' motor skill. When implemented properly, these techniques can be useful tools for physical educators, coaches, and physical activity professionals. The current study also demonstrated additional variables can influence the effectiveness of these interventions. The secondary purpose of the study was to examine whether the moderator variables (i.e., gender, age, behavioral principle used, setting, and skill) influenced the effect of the behavioral interventions. The results indicate all five moderators had an impact on the effects of the interventions.

Thomas and French (1985) identified slight gender differences in the performance of several motor tasks. Similarly, Dorfberger, Adi-Japha, and Karni (2009) discovered gender differences in the acquisition of several motor skills. The results of the moderator analysis for gender in the current study support the findings of this previous research. The ESLORS calculated for different gender groups indicated behavioral interventions had a moderate impact in studies that included males and females together (Rescaled ES = 0.62), a moderate to strong impact in studies with females (Rescaled ES = 0.77), and a strong impact in studies with males (Rescaled ES = 0.87). This suggests a behavior analytic intervention in an attempt to improve a motor skill may have a greater impact on males than it does on females or groups with both males and females. Dorfberger et al. suggested the greater capacity for motor learning may be a result of biological development differences found in males and females. In the current meta-analysis, the differential effects of behavioral interventions administered to males and females may be a result of these biological differences. However, all gender groupings showed at least a moderate improvement in motor skills. The results for the both variable should be evaluated with caution due to the small amount of ESs calculated for that group (*n* = 12). Whether teachers or coaches instruct males, females, or mixed-gender groups, the results of the current study suggest they can expect to see improved motor skill acquisition if behavioral principles are utilized.

Thomas and French (1985) also identified several motor performance tasks in which motor performance differences between males and females were related to age. Additionally, Dorfberger et al. (2009) also found differences in motor learning based on age. The results of the current meta-analysis support these findings as well; differences in the effects of behavior analytic interventions on motor skills based on age group were identified. The ESLORS calculated for different age groups indicated a moderate impact in studies with elementary-aged participants (Rescaled ES = 0.64), a moderate to strong impact in studies with secondary students (Rescaled ES = 0.77), and a strong impact in studies with college and adult participants (Rescaled ES = 0.99). These results indicate behavioral interventions may have a greater impact on older participants (i.e., college/adult population) than on younger participants. These findings corroborate the conclusions drawn by Dorfberger et al. in that capacity for motor learning increased as participants aged into adolescence. The effectiveness of the interventions may be related to the age of the participants; older participants may have been more receptive to the behavioral techniques due to their increased developmental capacity for motor learning. Despite these slight differences, the moderator analysis showed at least a moderate improvement in motor skills across all age groups. Elementary and secondary physical educators, coaches of children and adults, as well as physical activity practitioners working with all ages should expect improvements in their students' and athletes' motor skill learning and performance when behavioral principles are used to target motor skill behaviors.

Donahue et al.'s (1980) review supported the use of reinforcement strategies and public postings as effective interventions to improve motor skill. Despite this recommendation of reinforcement and public postings being more than 30 years old, the current meta-analysis supports the findings; studies that used reinforcement-based interventions produced a moderate to large effect on motor skill acquisition (Rescaled ES = 0.75), and studies that used public posting interventions had a large effect (Rescaled ES = 0.83). However, the current study also identified a wider variety of behavioral interventions that aided in motor skill acquisition. Studies that used a goal setting intervention had the highest ES (Rescaled ES = 1.04), and peer interventions had the lowest (Rescaled ES = 0.71). Although studies that used peer interventions produced the lowest mean ES, results still indicated a moderate to high effect on the acquisition of motor skills. In addition, package interventions (i.e., interventions in which two or more behavioral principles were administered simultaneously) were also shown to have a large effect on motor skills (Rescaled ES = 0.97). However, Lee (1993) suggested further research needs to be conducted to examine what component(s) of the package intervention are most effective across a range of settings. To address this issue, Kennedy (2005) suggested employing alternating treatments methodology to assess response differentiation between components of package interventions, thus identifying which component(s) of the package produced the most drastic change in behavior. Despite slight differences in the mean ESs across interventions, one could conclude all of the behavioral interventions included in the meta-analysis had a considerable impact on the acquisition of motor skills. Physical educators and coaches can implement these types of interventions within their own physical activity settings with reasonable confidence in their effectiveness. Physical activity practitioners can use public postings, goal setting techniques, reinforcement strategies, and package interventions to help their pupils in the acquisition of motor skills.

In addition, the impact of the setting in which the intervention was implemented was evaluated. Mainstream physical education classes and sport settings were found to have a strong positive effect on skill improvement (Rescaled ES = 0.85 and 0.83, respectively). Integrated physical education settings produced a rescaled ES of 0.65, which indicates a moderate effect (the total number of ESs calculated for this subpopulation was only nine; this category's results should be evaluated accordingly). Despite these slight differences in mean ESs, behavioral interventions were found to be moderately to strongly effective across all settings. However, the differential effects of behavior analytic interventions on motor skill across settings may perhaps be more of a function of the initial skill level of the participants typically found in that particular setting rather than the actual setting itself. For example, one may assume the initial skill level of members of a college athletic team (i.e., setting would fall under the category of "sport") is higher than that of students enrolled in a university-level physical education course (i.e., setting would be classified as "physical education"); differences in motor skill improvement may be due to the participants' initial skill level as opposed to the setting in which the intervention was introduced. To further exemplify this, when discussing the effects of a self-cueing technique on tennis skill acquisition, Lee (1993) asked, "Would the same technique be effective with children, whose behavior may be less directly under verbal control? Could it be used with advanced players, or is it only useful at lower skill levels?" (p. 314). The intervention in question was found to be successful in a physical education setting. But was the success because of some component of the nature of the physical education setting or because it was administered to participants with a low initial skill level associated with that physical education setting? Further research examining the impact of initial skill level on the effectiveness of behavioral interventions in activity settings is needed to answer these questions.

Studies that measured the effects of behavioral interventions on football and tennis skills produced strong mean ESs (Rescaled ES = 0.96 and 1.13, respectively). As mentioned previously, studies conducted with college and adult participants produced higher ESs than the other age groups, presumably due to developmental differences as discussed by Dorfberger et al. (2009). It should be noted that many of the studies that measured tennis and football skills were conducted in college physical education or college sports team settings. There may be an association between the college and adult age group mean ES and the mean ESs produced by football and tennis studies. It is unknown whether the skills the participants were learning (i.e., football and tennis skills) or the age of the participants learning those skills had a more impactful influence as a moderating variable. It was also found that behavioral interventions that were intended for volleyball skills produced the lowest mean ESLOR (Rescaled ES = 0.19), indicating a small effect. Several of the studies that measured volleyball skills were conducted with elementary-aged participants. As mentioned previously, interventions given to elementary-aged participants produced the lowest mean ES when compared to the other age groups. There may also be an association between the moderate elementary-aged group mean ES and the small mean ES for volleyball. Also, it should be noted that volleyball skills may be more difficult skills to master, especially for younger children; this may have impacted the results as well. However, based on the results of the current meta-analysis, behavioral interventions were effective in improving most of the skill categories (with the exception of volleyball skills). Physical educators should feel confident in the potential effectiveness of using behavioral techniques when teaching skills across a variety of activities.

For the current study, we chose to categorize skills based on the sport or activity in which the skill is used. Another perspective future researchers may want to consider is the examination of the acquisition of open skills (i.e., motor skills that are performed in a constantly variable environment with conditions that are changing, such as a basketball dribble against defenders; Siedentop & Tannehill, 2000) versus closed sport skills (i.e., motor skills that are performed in a fixed environment in which environmental conditions remain unchanged during the skill performance, such as a volleyball serve; Siedentop & Tannehill, 2000). Lee (1993) noted the uniqueness in learning and performing open skills, which involves response generalization and stimulus discrimination. Future research should focus on the effects of behavior analytic interventions on open and closed skills across all of the sports included in this meta-analysis.

One limitation of the current study is associated with analyzing nonindependent data. That is, varying amounts of ESs were extracted from the same study. For example, one study (i.e., Smith & Ward, 2006) yielded 27 ESs and another (Grant, Ballard, & Glynn, 1990) produced only two. One could argue using nonindependent data may affect the reliability of the results of the current study. To address this issue, Lipsey and Wilson (2001) suggested randomly selecting one ES from each included study and comparing the average of these ESs to the overall mean effect size. When using this method, we found the average of the randomly selected ESs also produced a large positive effect (rescaled ES = 0.84), similar to the overall ES as found in our original data analysis. Using nonindependent data in the current meta-analysis does not appear to considerably influence the results. Additionally, as with any meta-analysis, there may be a degree of publication bias (Lipsey & Wilson, 2001). The included studies were limited to those that were available in journals, doctoral dissertations, or master's theses. There may be additional studies that were not published because their results were not found to be notable. This may bias the current study's findings.

The results of this meta-analysis indicate behavior analytic interventions can be beneficial to a range of populations in a variety of settings on the acquisition of motor skills. Future research should be conducted focusing on the interaction effects of the moderating variables on motor skills. For example, future studies could examine the possible reasons why behavioral interventions have a large effect on tennis skills, but a small effect on volleyball skills. Also, as discussed earlier, future research should focus on the effects of interventions based in behavior analysis on the acquisition of open and closed skills.

Conclusion

The results of the current meta-analysis study indicate interventions based in applied behavior analysis had a strong and positive effect on the improvement of motor skills. The overall random ES_{LOR} was 1.49 (Rescaled ES = 0.81), which indicates a significant improvement in motor skill performance. Although slight differences in the effectiveness of the interventions were found based on the age and gender of the participants, the setting of and behavioral principle used in the intervention, and the skill targeted for improvement, it can be concluded ABA-based teaching techniques can be useful across a variety of learners, settings, and skills. Physical education teachers and sport coaches should take note: Teaching techniques based in applied behavior analysis can aid in the improvement of their students' and athletes' motor skills.

There are numerous practical applications for physical educators, coaches, and other physical activity practitioners. The behavior analysis-based techniques, as found in public postings, reinforcement strategies, peer-based interventions, and others (as described above) can be used to improve sport skills and other movement forms. The teacher or coach can decide which type of behavior to reinforce. If a sport skill behavior is reinforced via social or tangible reinforcement, the likelihood of repeated correct performance increases. Likewise, if other movement forms are reinforced, they will also be repeated by the individual(s) to whom the reinforcement was given. The possibilities of behavioral applications within physical activity contexts are seemingly endless. Teachers and coaches have the ability to select target behaviors, administer reinforcement when a student properly engages in the target behavior, and observe the subsequent behavior changes that occur.

References

Study included in the meta-analysis.

Alberto, P. A., & Troutman, A. C. (2006). *Applied behavior analysis for teachers* (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

*Allison, M. G., & Ayllon, T. (1980). Behavioral coaching in the development of skills in football, gymnastics, and tennis. *Journal of Applied Behavior Analysis, 13*, 297–314.

Ashy, M. H., Lee, A. M., & Landin, D. K. (1988). Relationship of practice using correct technique to achievement in a motor skill. *Journal of Teaching in Physical Education, 7*, 115–120.

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*, 2137–2144.

Buck, M., Harrison, J. M., & Bryce, G. R. (1990). An analysis of learning trials and their relationship to achievement in volleyball. *Journal of Teaching in Physical Education, 10*, 134–152.

*Buzas, H. P., & Ayllon, T. (1981). Differential reinforcement in coaching tennis skills. *Behavior Modification, 5*, 372–385.

Campbell, J. M. (2004). Statistical comparison of four effect sizes for single-subject design. *Behavior Modification, 28*, 234–246.

Christensen, L. B. (2007). *Experimental methodology* (10th ed.). Boston, MA: Pearson.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (2nd ed.). Upper Saddle River, NJ: Pearson.

*Crouch, D. W., Ward, P., & Patrick, C. A. (1997). The effects of peer-mediated accountability on task accomplishment during volleyball drills in elementary physical education. *Journal of Teaching in Physical Education, 17*, 26–39.

Donahue, J. A., Gillis, J. H., & King, K. (1980). Behavior modification in sport and physical education: A review. *Journal of Sport Psychology, 2*, 311–328.

Dorfberger, S., Adi-Japha, E., & Karni, A. (2009). Sex differences in motor performance and motor learning in children and adolescents: An increasing male advantage in motor learning and consolidation phase gains. *Behavioural Brain Research, 198*, 165–171.

*Fitterling, J. M., & Ayllon, T. (1983). Behavioral coaching in classical ballet. *Behavior Modification, 7*, 345–368.

*Grant, B. C., Ballard, K. D., & Glynn, T. L. (1990). Teacher feedback intervention, motor-on-task behavior, and successful task performance. *Journal of Teaching in Physical Education, 9*, 123–139.

Fueyo, V., & Bushell, D. (1998). Using number line procedures and peer tutoring to improve the mathematics computation of low-performing first graders. *Journal of Applied Behavior Analysis, 37*, 417–430.

Hands, B. (2008). Changes in motor skill and fitness measures among children with high and low motor competence: A five-year longitudinal study. *Journal of Science and Medicine in Sport, 11*, 155–162.

Harris, V. W., & Sherman, J. A. (1973). Use and analysis of the good behavior game to reduce disruptive classroom behavior. *Journal of Applied Behavior Analysis, 6*, 405–417.

Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *British Medical Journal, 327*, 557–560.

*Houston-Wilson, C., Dunn, J. M., van der Mars, H., & McCubbin, J. (1997). The effect of peer tutors on motor performance in integrated physical education classes. *Adapted Physical Activity Quarterly, 14*, 298–313.

*Hupp, S. D., & Reitman, D. (1999). Improving sports skills and sportsmanship in children diagnosed with attention-deficit/hyperactivity disorder. *Child and Family Behavior Therapy, 21*, 35–51.

Ingham, P., & Greer, R. D. (1992). Changes in student and teacher responses in observed and generalized settings as a function of supervisor observations. *Journal of Applied Behavior Analysis, 25*, 153–164.

*Johnson, M., & Ward, P. (2001). Effects of classwide peer tutoring on correct performance of striking skills in 3rd grade physical education. *Journal of Teaching in Physical Education, 20*, 247–263.

Kennedy, C. H. (2005). *Single-case designs for educational research*. Boston, MA: Allyn and Bacon.

*Kladopoulos, C. N., & McComas, J. J. (2001). The effects of form training on foul-shooting performance in members of a women's college basketball team. *Journal of Applied Behavior Analysis, 34*, 329–332.

*Komaki, J., & Barnett, F. T. (1977). A behavioral approach to coaching football: Improving the play execution of the offensive backfield on a youth football team. *Journal of Applied Behavior Analysis, 10*, 657–664.

Lalli, J. S., Browder, D. M., Mace, F. C., & Brown, D. K. (1993). Teacher use of descriptive analysis data to implement interventions to decrease students' problem behaviors. *Journal of Applied Behavior Analysis, 26*, 227–238.

Lee, C. (1993). Operant strategies in sport and exercise: Possibilities for theoretical development. *International Journal of Sport Psychology, 24*, 306–325.

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage.

McKenzie, T. L., & Rushall, B. S. (1974). Effects of self recording on attendance and performance in a competitive swimming environment. *Journal of Applied Behavior Analysis, 7*, 199–206.

*Melody, D. W. (1990). *The influence of self-modeling upon free-throw shooting* (Doctoral dissertation). Retrieved from Dissertations & Theses: Full Text database.

Miller, D. L., & Kelley, M. L. (1994). The use of goal setting and contingency contracting for improving children's homework performance. *Journal of Applied Behavior Analysis, 27*, 73–84.

National Association for Sport and Physical Education. (2004). *Moving into the future: National standards for physical education* (2nd ed.). Reston, VA: Author.

Rink, J. E. (2003). Effective instruction in physical education. In S. Silverman & C. Ennis (Eds.), *Student learning in physical education* (2nd ed., pp. 165–186). Champaign, IL: Human Kinetics.

*Rush, D. B., & Allyon, T. (1984). Peer behavioral coaching: Soccer. *Journal of Sport Psychology, 6*, 325–334.

*Shapiro, E. S., & Shapiro, S. (1985). Behavioral coaching in the development of skills in track. *Behavior Modification, 9*, 211–224.

Siedentop, D., & Rushall, B. (1972). An operant model for skill acquisition. *Quest, 17*, 82–90.

Siedentop, D., & Tannehill, D. (2000). *Developing teaching skills in physical education* (4th ed.). Mountain View, CA: Mayfield.

Silverman, S. (1985). Relationship of engagement and practice trials to student achievement. *Journal of Teaching in Physical Education, 5*, 13–21.

Silverman, S. (2011). Teaching for student learning in physical education. *Journal of Physical Education, Recreation, and Dance, 82*, 29–34.

*Smith, S. L., & Ward, P. (2006). Behavioral interventions to improve performance in collegiate football. *Journal of Applied Behavior Analysis, 39*, 385–391.

Stodden, D., Langendorfer, S., & Roberton, M. A. (2009). The association between motor skill competence and physical fitness in young adults. *Research Quarterly for Exercise and Sport, 80*, 223–229.

Thomas, J. R., & French, K. E. (1985). Gender differences across age in motor performance: A meta-analysis. *Psychological Bulletin, 98*, 260–282.

Walberg, H. J. (1984). Improving the productivity of America's schools. *Educational Leadership, 41*, 19–27.

*Wanlin, C. M., Hrycaiko, D. W., Martin, G. L., & Mahon, M. (1997). The effects of a goal-setting package on the performance of speed skaters. *Journal of Applied Sport Psychology, 9*, 212–228.

Ward, P., & Barrett, T. (2002). A review of behavior analysis research in physical education. *Journal of Teaching in Physical Education, 21*, 242–266.

*Ward, P., & Carnes, M. (2002). Effects of posting self-set goals on collegiate football players' skill execution during practice and games. *Journal of Applied Behavior Analysis, 35*, 1–12.

*Ward, P., Crouch, D. W., & Patrick, C. A. (1998). Effects of peer mediated accountability on opportunities to respond and correct skill performance by elementary school children in physical education. *Journal of Behavioral Education, 8*, 103–114.

*Ward, P., Smith, S. L., Makasci, K., & Crouch, D. W. (1998). Differential effects of peer-mediated accountability on task accomplishment in elementary physical education. *Journal of Teaching in Physical Education, 17*, 442–452.

*Ward, P., Smith, S. L., & Sharpe, T. (1997). The effects of accountability on task accomplishment in collegiate football. *Journal of Teaching in Physical Education, 17*, 40–51.

*Wilson, A. E. (1988). *Application of multiple behavioral procedures in junior high school sport* (Doctoral dissertation). Retrieved from Dissertations and Theses: Full Text database.

*Wolko, K. L., Hrycaiko, D. W., & Martin, G. L. (1993). A comparison of two self-management packages to standard coaching for improving practice performance of gymnasts. *Behavior Modification, 17*, 209–223.

*Ziegler, S. G. (1987). Effects of stimulus cueing on the acquisition of groundstrokes by beginning tennis players. *Journal of Applied Behavior Analysis, 20*, 405–411.