Psychology of Sport & Exercise 43 (2019) 301–310

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

Balance confidence scale: Preliminary validity, reliability, and relation to neural excitability in young adults

Tulika Nandi[a,1], Rebecca Lewthwaite[a,b], Beth E. Fisher[a], George J. Salem[a,*]

[a] Division of Biokinesiology and Physical Therapy, University of Southern California, 1540 Alcazar St, CHP-155, Los Angeles, CA, 90089-9006, USA
[b] Rancho Los Amigos National Rehabilitation Center, Downey, CA, USA

ARTICLE INFO

Keywords:
Balance confidence
Self-efficacy
Validity
Neural excitability
TMS

ABSTRACT

Balance confidence may reflect and affect balance performance, and this effect may be mediated by neural inputs to muscles. Available balance confidence scales are designed for older adults and individuals with pathological conditions. To eliminate ceiling effects for young adults and to enable the study of neural excitability in relation to confidence relevant to balance, we developed a Balance Confidence Scale (BCS), comprised of items depicting single limb stance conditions of varying difficulty. Motor cortical excitability was measured using transcranial magnetic stimulation (TMS). Preliminary construct validity was examined relative to balance performance, perceived steadiness, and previous physical activity in 20 young adults (25.7 ± 4.2 years; 11 females). The scale showed good internal consistency (Cronbach's $\alpha = 0.81$) and good test-retest reliability ($ICC_{2,1} = 0.84$) in a separate sample of 21 young adults (23.8 ± 4.6 years; 11 females). Balance confidence ranged from 34 to 79.6% in the validity sample. Confidence was correlated with performance indexed using center of pressure velocity ($r = -0.62$, $p = 0.01$) and area ($r = -0.49$, $p = 0.04$), in a relatively difficult standing condition with one leg positioned on an unstable spring. Perceived steadiness and overall physical activity were not correlated with confidence; however, participants with higher confidence scores reported greater experience with balance-related activities. Finally, confidence was related to indices of motor cortical excitability. The Balance Confidence Scale has sound preliminary validity and reliability and holds promise for the study of neural processes mediating social-cognitive influences on balance performance.

1. Introduction

Balance is essential for successful engagement in many human activities. Diverse populations, including trained athletes, exhibit a wide range of balance capabilities which in turn have implications for motor and sport performance (Kiers, van Dieën, Dekkers, Wittink, & Vanhees, 2013) as well as injury risk (McKeon & Hertel, 2008). Self-efficacy, the sense that one can successfully execute the actions or behavior required to produce outcomes (Bandura, 1977), often considered task-specific confidence, can both reflect and contribute to motor performance (McKay, Lewthwaite, & Wulf, 2012; Moritz, Feltz, Fahrbach, & Mack, 2000; Woodman & Hardy, 2003; Wulf & Lewthwaite, 2016). Specifically, balance confidence has been related to postural sway and falls, as well as athletic performance (K. L. Gao, Hui-Chan, & Tsang, 2011; Hatch, Gill-Body, & Portney, 2003; McAuley & Gill, 1983; Myers et al., 1996; Schepens, Goldberg, & Wallace, 2010; Talley, Wyman, & Gross, 2008; Weiss, Wiese, & Klint, 1989).

Confidence is a particular form of expectations that collectively refer to anticipatory or predictive beliefs or cognitions about what is to occur and may index the expected likelihood of rewarding experiences or outcomes (Wulf & Lewthwaite, 2016). There is growing evidence that expectancies can shape neural inputs to muscles, and consequently influence performance (Arias et al., 2014; Fiorio, Emadi Andani, Marotta, Classen, & Tinazzi, 2014; Gupta & Aron, 2011; Klein, Olivier, & Duque, 2012; Mooshagian, Keisler, Zimmermann, Schweickert, & Wassermann, 2015; Thabit et al., 2011; Themanson et al., 2008; Themanson & Rosen, 2015; Wulf & Lewthwaite, 2016). Both corticospinal excitability (CSE) and primary motor cortex (M1) excitability

* Corresponding author. Musculoskeletal Biomechanics Research Laboratory (MBRL), Division of Biokinesiology & Physical Therapy, 1540 Alcazar St, CHP-155, Los Angeles, CA, 90089-9006, USA.

E-mail addresses: nandi@pt.usc.edu (T. Nandi), rlewthwaite@dhs.lacounty.gov (R. Lewthwaite), bfisher@pt.usc.edu (B.E. Fisher), gsalem@pt.usc.edu (G.J. Salem).

[1] The first author is also affiliated with the Center for Human Movement Sciences, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands.

https://doi.org/10.1016/j.psychsport.2019.04.004
Received 1 May 2018; Received in revised form 30 January 2019; Accepted 3 April 2019
Available online 09 April 2019
1469-0292/

have been examined in relation to outcome expectations that refer to an individual's belief that a given behavior when performed by self or others (e.g., taking a dietary supplement) will lead to certain outcomes (e.g., well-being). Neural processes shaped by expectations can influence performance; however, neural excitability has not been examined in relation to personal performance expectations or confidence.

In young adults, balance performance quantified using postural sway and the neural excitability of leg muscles differ considerably between individuals even while standing (Nandi et al., 2018; Nandi, Fisher, Hortobágyi, & Salem, 2018). In this population, confidence may be shaped by a variety of individual factors including recent experience and history of physical activity. Therefore, we hypothesized that balance confidence is a measurable construct that may partially explain variations in performance and neural excitability. However, currently available measures, such as the Activities-specific Balance Confidence (ABC) scale are designed to assess balance confidence across a range of walking related everyday activities in older adults and individuals with conditions such as amputation and stroke (Botner, Miller, & Eng, 2005; Myers et al., 1996). Consequently, a ceiling effect is encountered when examining ostensibly healthy or skilled populations. Furthermore, the balance-related activities which may be feasibly examined in fixed-location transcranial magnetic stimulation (TMS) paradigms (e.g. single limb stances), are distinct from those mobility-related activities described in available balance confidence measures. Therefore, we developed the Balance Confidence Scale (BCS) which included circumstances, derived from the balance literature, that quantified participants' balance confidence during single limb stance (SLS). Stability in SLS is important because it is a key component of everyday activities such as gait, pivoting, obstacle crossing, stair climbing and reaching to a high shelf. Additionally, SLS stability remains impaired for more than a year after ankle surgery (Nilsson, Ageberg, Ekdahl, & Eneroth, 2006), can distinguish individuals with ankle instability (Tropp & Odenrick, 1988), and is predictive of injuries (Mcguine, Greene, Best, & Leverson, 2000; Trojian & McKeag, 2006; Tropp, Ekstrand, & Gillquist, 1984). Further, greater SLS stability is observed in more experienced athletes (Hahn, Foldspang, Vestergaard, & Ingemann-Hansen, 1999; Paillard et al., 2006) and athletes engaged in activities such as dance and gymnastics that specifically challenge balance (Asseman, Caron, & Crémieux, 2008; Bressel, Yonker, Kras, & Heath, 2007; Gerbino, Griffin, & Zurakowski, 2007; Vuillerme et al., 2001). Both theoretical (Bandura, 1977) and behavioral observations (Abbas & North, 2017; Reinhard & Dickhäuser, 2009; Themanson & Rosen, 2015) suggest that confidence has a greater influence on motor performance when task difficulty or challenge is at least moderately high. Thus, assessment of balance confidence should depict variations in balance task difficulty, including removal of visual input, restriction of the base of support (BOS), and/or increased surface height (Carpenter, Adkin, Brawley, & Frank, 2006; Cleworth & Carpenter, 2016; Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996; Schieppati, Tacchini, Nardone, Tarantola, & Corna, 1999).

Our **primary aim** was to design a measure of balance confidence to examine the influence of confidence on balancing capabilities in healthy young adults, and to provide evidence related to the measure's preliminary validity and reliability. Our secondary aim was to examine the association between confidence and neural excitability and thereby test the hypothesis that confidence is one factor accounting for individual differences in neural excitability and performance while balancing. Specifically, we examined indices of motor cortex (M1) inhibition and facilitation that contribute to the control of muscle activations, influence center of pressure (COP) movements and likely ensure that the neuromuscular system is optimally prepared to respond to perturbations in standing (Nandi et al., 2018; Nandi, Fisher, et al., 2018; Papegaaij, Baudry, Négyesi, Taube, & Hortobágyi, 2016; Papegaaij, Taube, Hogenhout, Baudry, & Hortobágyi, 2014).

2. Methods

2.1. Participants

Twenty healthy adults (25.7 ± 4.2 years; 11 females) participated in a single 2.5 h laboratory visit during which BCS validity and neural excitability were examined (Nandi, Fisher, et al., 2018). A separate, independent, sample of 21 participants (23.8 ± 4.6 years; 11 females) completed the BCS on 2 days, approximately one week apart, to determine test-retest reliability. Participants with ongoing symptoms due to lower extremity injury were excluded. In accordance with TMS safety guidelines, participants were excluded if they reported a history of neurological disorders, seizures, head trauma or unexplained loss of consciousness; were pregnant; had metal implants or pacemakers; had used medication known to lower seizure threshold or had blood relatives with a history of seizures. Written informed consent was obtained and all study procedures were conducted in accordance with the Declaration of Helsinki. The study was approved by the Institutional Review Board of the University of Southern California, Health Sciences Campus.

2.2. Procedures

Upon arrival at the laboratory, the informed consent and TMS safety questionnaire were completed, followed by the International Physical Activity Questionnaire (IPAQ) and BCS. Subsequently, force plate and TMS data were collected in the four physical test conditions.

2.2.1. Balance confidence scale

Participants completed the BCS in which they were asked to rate how confident they were that they could stay still for 1 min under each photographically depicted posture (see Appendix). The BCS included circumstances, derived from the balance literature, that quantified participants' balance confidence during differing challenges in single limb stance. Responses on each item were marked on a 10-cm visual analog scale where 0 and 10 represented 'not confident at all' and 'extremely confident', respectively. Individual item scores (max. 10) and the total score (maximum 80) obtained by summing responses to all questions, were expressed as a percentage with 0 and 100% reflecting 'not confident at all' and 'extremely confident' respectively. Twenty-one additional participants completed the questionnaire twice (one week apart) for test-retest reliability examination. Participants did not practice or directly experience any of the postures in the questionnaire at any point during the laboratory visit.

2.2.2. Construct validity

2.2.2.1. Balance performance: center of pressure. Construct validity of the BCS was evaluated by examining the relations between confidence and balance performance (e. g., Myers et al., 1996). To quantify balance performance, COP position was recorded at 1500 Hz using 2 AMTI force platforms (Model #OR6-6-1, 127 Watertown, MA) and the data were stored using Qualisys software (Qualisys Inc., Gothenburg, Sweden). COP dynamics were examined by placing individuals under challenging balance conditions that were similar but not identical to those depicted in the balance confidence measure. In the physical test conditions, balance difficulty was manipulated by narrowing the base of support (BOS) and the use of unstable surfaces. Participants completed the following physical *test conditions*: 1) standing with feet shoulder width apart (i.e., wide stance; 2WB); 2) standing with feet as close together as possible (i.e., narrow stance; 2NB); 3) standing with one foot on a solid block (1Step), ~30 cm high; and 4), and standing with one foot on an unstable spring (1Spring) ~30 cm high, stiffness – 49.04 N/cm. In 2WB, participants self-selected a comfortable foot position and this condition was used for comparison with the other postures. For 1Step and 1Spring, the dominant foot chosen based on responses to 3 questions (Hebbal & Mysorekar, 2006) was designated as the lower stance leg. Additionally, participants were instructed to maintain the majority of their body weight (at least 80%) on the stance leg and the extent to which this instruction was followed was confirmed during post-hoc analysis of force plate data. In all conditions, participants were instructed to 'stay as still as possible'. The testing in each condition lasted for approximately 4–5 min with 1–2 breaks in between, as requested by participants. COP data were filtered using a 4th order low pass Butterworth filter with a 10 Hz cut off. COP velocity was calculated by summing the absolute displacement between every consecutive data point (3000 data points in 2 s) and dividing this total distance by the time. Values were averaged over 30 trials (see neural excitability methods below) to obtain a single estimate for each *test condition*. COP and TMS data were measured during the same trials to minimize the time burden for participants. However, COP velocity was estimated in a 2s window before the TMS pulse to ensure that it was not influenced by the TMS.

2.2.2.2. Perceived steadiness. Individuals' perceptions of their steadiness while balancing capabilities were also examined. Perceived movement or steadiness in the each of the *test conditions* was quantified using the following question – 'During the last trial, how would you rate your quality of stillness, with 10 being very still and 0 being very unstill. You may use half points' (Schieppati et al., 1999). The question was asked immediately after the participants practiced each *test condition*.

2.2.2.3. Previous experiences. Finally, since confidence is expected to be influenced by previous experiences, we included a self-reported general physical activity score and a qualitative assessment regarding participants' experience with athletic activities that challenge balance. The self-report International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) was used to quantify general physical activity history in metabolic equivalents (METs). Additionally, participants were asked about their experience, during the last 5 years, with the following balance related activities: skateboarding, skiing, snowboarding, ice skating, rollerblading, slacklining, ballet or others (asked to specify). For each activity, participants were asked to categorize their skill level as beginner (B), moderately skilled (MS) or elite (E) performer.

2.2.3. Neural excitability

The protocol for neural excitability testing is described in detail in a previous paper (Nandi, Fisher, et al., 2018; see Fig. 1). Transcranial magnetic stimulation (TMS) pulses were delivered using a double cone coil and 2 single-pulse magnetic stimulators (Magstim Model 200^2) connected by a Bistim module (The Magstim Co., Whitland, UK). Motor evoked potentials (MEPs) were recorded from the dominant side tibialis anterior (TA) using a bipolar surface electromyography (EMG) electrodes (inter-electrode distance 17 mm, Motion Lab Systems, Baton Rouge, LA). EMG data were acquired at 15,000 Hz and stored using Signal software (v6, Cambridge Electronic Design Ltd, Cambridge UK). The tibialis anterior (TA), a primary ankle invertor, was chosen because it plays an important role in maintaining balance, especially when BOS decreases (Lemos, Imbiriba, Vargas, & Vieira, 2015; Sozzi, Honeine, Do, & Schieppati, 2013; Winter, Prince, Frank, Powell, & Zabjek, 1996). Motor threshold (MT) was defined as the lowest intensity at which 3 out of 5 MEPs had peak-to-peak amplitude of at least 100 μV (Papegaaij et al., 2014). Motor evoked potentials (MEPs) obtained using a single pulse are an index of corticospinal excitability. M1 inhibition and facilitation were quantified using the short interval intracortical inhibition (SICI) and intracortical facilitation (ICF) protocols, respectively. Specifically, SICI and ICF were measured by applying 2 pulses separated by 3 and 13 ms inter-stimulus intervals (ISI), respectively. The first, conditioning pulse was subthreshold (80% MT), while the subsequent test pulse was supra-threshold (120% MT). Ten paired pulses each for the SICI and ICF protocols and 10 single pulses at 120% MT were applied in random order. Therefore, a total of 30 trials were recorded with at least 5 s between trials.

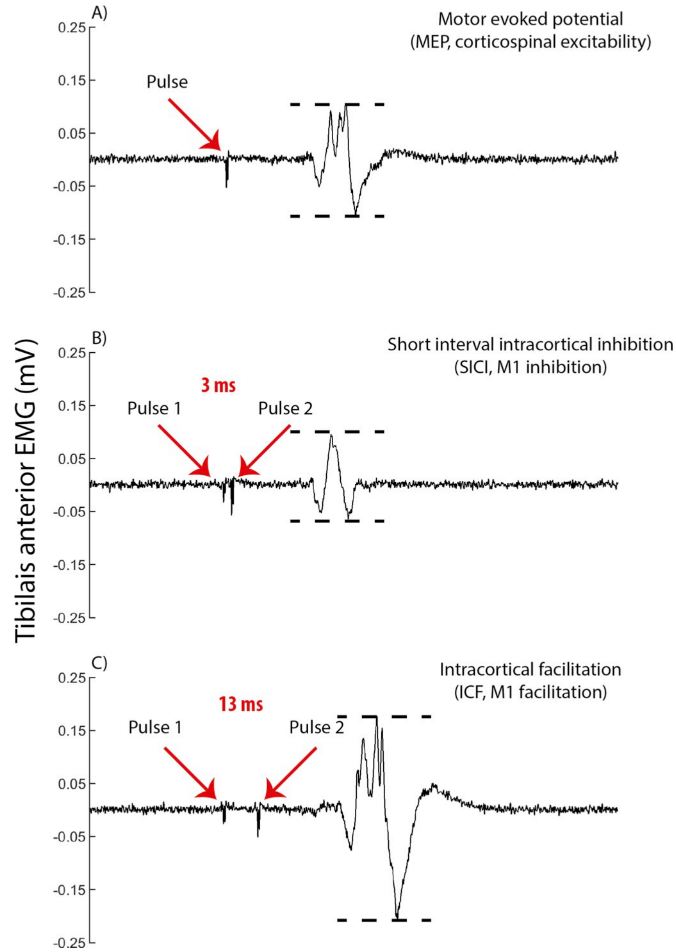


Fig. 1. Sample EMG traces from one participant showing the relative timings of TMS pulses and the EMG response. The horizontal dotted lines depict the estimation of peak-to-peak MEP amplitude. Panels A to C show the test MEP, inhibited MEP and facilitated MEP respectively.

Data were processed using Signal software and Matlab (The Mathworks, Natick, MA). MEP amplitude was defined as the peak-to-peak voltage in a 25–65 ms window after application of the pulse. The test MEP is obtained from single pulse trials while the conditioned MEPs for SICI and ICF are obtained from the 3 ms and 13 ms ISI double pulse trials, respectively.

1. SICI = ($Conditioned_{SICI}$/Test MEP *100); smaller values indicate greater inhibition.
2. ICF = ($Conditioned_{ICF}$/Test MEP *100); higher values indicate greater facilitation.

Ten trials were averaged for each outcome variable to obtain a single estimate for each condition. Additionally, the difference in MEP, SICI, and ICF between wide stance and the more difficult conditions was calculated to obtain an estimate of the neural response to increasing difficulty of balance conditions.

2.3. Statistical analyses

SPSS (Version 22, Armonk, NY, IBM Corp.) software was used for all statistical analyses. Cronbach's α coefficient and $ICC_{2,1}$ were used for estimating internal consistency and test-retest reliability, respectively. Correlation analyses were conducted for estimating associations between confidence (total score expressed as a percentage) and COP velocity, perceived steadiness, and IPAQ scores. Correlation between confidence and perceived steadiness was examined using data pooled across all 4 test conditions (Schieppati et al., 1999). Additionally, correlations between confidence and neural excitability (i.e. MEP, SICI and ICF), and delta neural excitability (i.e., difference between 2WB and other test conditions) were examined. Significance level was set at 0.05. Using the Shapiro-Wilk test it was determined that measures were not normally distributed in one or more conditions. Spearman correlation coefficients were computed for these conditions. A scatter plot was used to visually estimate whether any data points appeared to have undue influence on the linear fit. Subsequently, as recommended by Stevens (Stevens, 1984), all data points with Cook's d > 1 were excluded from the correlation analysis.

3. Results

3.1. Descriptive data, internal consistency, and test-retest reliability

Total BCS scores ranged from 34 to 79.6% (56 ± 12.5%). Good internal consistency was confirmed by a Cronbach's α coefficient of 0.81. Item difficulty characterized by the depicted circumstances (i.e., eyes open or closed, BOS small or large, and surface height low or high) was reflected in individual item scores (Table 1). Highest and lowest scores were observed in the following conditions, respectively: SLS with eyes open, arms crossed across the chest; and SLS at the edge of a high block, with small BOS, eyes closed, arms crossed across the chest. The BCS had good test-retest reliability with an $ICC_{2,1}$ of 0.84.

3.2. Construct validity

Confidence scores were negatively correlated with COP velocity ($r = -0.62$, $p = 0.01$) and area ($r = -0.49$, $p = 0.04$) in the most difficult test condition (i.e., 1Spring; Table 2, Fig. 2), after removal of one statistical outlier (Cook's d > 1; Stevens, 1984).

Perceived steadiness, assessed regarding the last trial in each test condition, was not correlated with confidence.

Confidence scores were not correlated with generic physical activity levels assessed using the IPAQ. Previous experience with balance related activities is reported in Table 3.

3.3. Neural excitability

3.3.1. Confidence and neural excitability

Confidence scores were significantly correlated with SICI in the most difficult condition (i.e., 1Spring, Spearman's rho = 0.46, $p = 0.046$) and with ICF in the easiest condition (i.e., 2WB Spearman's rho = 0.57, $p = 0.013$), after removal of one statistical outlier (Cook's d > 1; Stevens, 1984) (Table 4). Confidence was not correlated with MEP in any condition.

Table 2
Correlations between Balance Confidence Scale scores and COP dynamics.

	2WB	2NB	1Step	1Spring
COP velocity	0.15	−0.05	−0.09	**−0.62***#
COP area	0.15	−0.02	0.06	**−0.49***#

Note: *Significant at $p < 0.05$, # indicates that one statistical outlier was removed. COP - center of pressure.

3.3.2. Confidence and delta neural excitability

Confidence scores were significantly correlated with the response to difficulty manipulation (i.e., the difference in ICF between wide stance, 2WB, and - 1Step and 1Spring; Table 5). None of the other (delta) excitability measures were correlated with confidence.

4. Discussion

The primary aim of this study was to examine preliminary construct validity and reliability of the BCS designed for young healthy or athletic populations. We found balance scores ranging from 34 to 79.6%, with a mean score of 56 (± 12.5%) in our sample of healthy young adults with varied experience in balance-related activities. This scoring distribution is desirable and indicates that the BCS questionnaire is suitable for this population and may not suffer from the ceiling effects expected in other measures. We found good internal consistency and test-retest reliability over a one-week interval. Confidence, however, is expected to be dynamic and may change in response to positive or negative balance-relevant experiences. The relationship between confidence and balance performance indexed using COP (rho = −0.62 and −0.49) was similar to the 0.37–0.61 range reported for the ABC scale (Myers et al., 1996). Confidence scores were not correlated with perceived steadiness or MET-equivalent generic physical activity scores. However, participants with higher BCS scores reported greater experience with balance-related activities. The secondary purpose was to examine neurophysiological processes, specifically CSE and M1 excitability, which can potentially mediate the effects of confidence on motor output. Confidence was correlated with M1-specific measures of excitability, particularly ICF, which may reflect M1 inputs from other brain areas (Di Lazzaro & Ziemann, 2013; Fedele et al., 2016; Ferreri et al., 2011).

4.1. Construct validity: balance performance

COP dynamics reflect the net neuromuscular response that controls spontaneous postural sway in standing (Winter et al., 1996). COP measurements are reliable, can consistently discriminate between

Table 1
Balance Confidence Scale individual item and total scores.

Item	Mean (%) [Standard deviation]
"How confident are you that you can stay still for 1 min in each of the following conditions:"	
SLS, with eyes open and arms crossed across the chest	84.7 [13.6]
SLS, at the edge of a high block with eyes open and arms crossed across the chest	74.0 [19.0]
SLS, with small BOS, with eyes open and arms crossed across the chest	62.0 [20.0]
SLS, with eyes closed and arms crossed across the chest	60.8 [18.0]
SLS, at the edge of a high block, with small BOS, with eyes open and arms crossed across the chest	51.0 [24.0]
SLS, at the edge of a high block with eyes closed and arms crossed across the chest	48.7 [17.9]
SLS, with small BOS, with eyes closed and arms crossed across the chest	38.4 [19.3]
SLS, at the edge of a high block, with small BOS, with eyes closed and arms crossed across the chest	28.3 [19.0]
Standing Balance Confidence Scale Total Score	**56 [12.5]**

Note: Items are presented in order from the sample's highest to lowest mean confidence. A photo accompanying each item depicted the described circumstance for participants (see Appendix). Scores range from 0 (not confident at all) and 100% (extremely confident).
SLS - single limb stance.

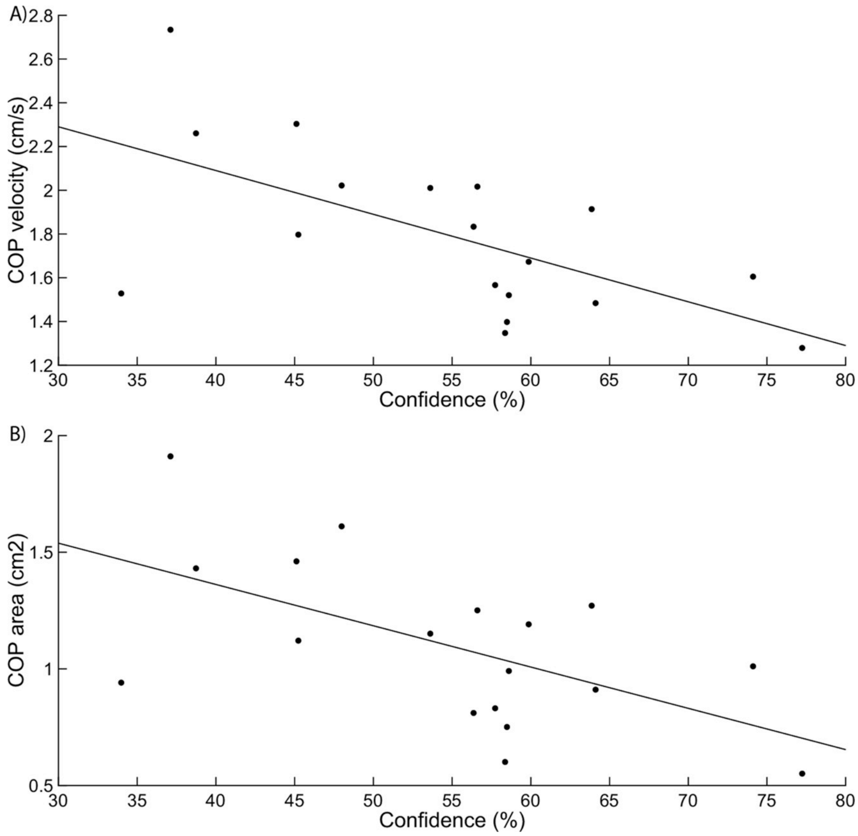


Fig. 2. Association between Balance Confidence Scale score and center of pressure (COP) dynamics in the most difficult 1Spring condition, A: COP velocity; B: COP area; * significant at $p < 0.05$.

different postures and populations, and are predictive of falls (Lin, Seol, Nussbaum, & Madigan, 2008; Melzer, Benjuya, & Kaplanski, 2004; Piirtola & Era, 2006; Ruhe, Fejer, & Walker, 2010). Specifically, COP velocity and area increase when sensory and mechanical manipulations increase absolute or perceived balance difficulty and are higher in populations with known balance deficits (Prieto et al., 1996). In line with this evidence, we found that relatively poor balance, indicated by higher COP velocity and area, was associated with lower confidence. Also, in agreement with self-efficacy theory that postulates greater influence of confidence on performance in more challenging tasks, the association between COP and confidence emerged in the most difficult test condition.

4.2. Construct validity: perceived steadiness

Based on self-efficacy theory, it is hypothesized that confidence can influence perceptions of success and/or performance (Motl, Konopack, Hu, & McAuley, 2006). For instance, high confidence is associated with both better performance and lower perceived exertion during an endurance task (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Rudolph & McAuley, 1996). However, the lack of association between confidence and perceived stability is not surprising. In standing balance tasks, previous studies have also found that confidence, measured prior to performance, and perceived performance, assessed after balance testing, can be independent of each other (Cleworth & Carpenter, 2016; Lamarche, Shaw, Gammage, & Adkin, 2009). We cannot rule out the possibility that confidence would affect perception if both constructs were evaluated using identical standing conditions. Alternatively, since perception was assessed immediately after actually performing the task, performance likely had a greater influence on perception, than confidence assessed earlier.

4.3. Construct validity: previous experiences

Bandura postulated that previous experiences and performance accomplishments are a major source of efficacy information (Bandura, 1977). Though there is some transfer of efficacy expectations to other tasks and situations, the effect of past performance is strongest on *task-specific* efficacy. While participants may not have previously experienced the particular conditions depicted in the BCS, SLS, visual feedback deprivation and BOS restrictions are components of many complex movements. For instance, reaching to a high shelf may require standing on one leg and balancing on a BOS limited to the forefoot. Such situations are even more likely to be encountered during athletic activities that challenge balance. Indeed, though general physical activity levels were not correlated with balance confidence, some patterns were observed in the distribution of confidence scores and reported experience with athletic activities (Table 3). All 3 participants with confidence scores more than 1SD lower than the mean (34–39%) reported no experience with balance-related activities. Of the 3 participants with confidence scores more than 1 SD higher than the mean (74–80%), 2 had extensive experience with skiing, snowboarding, ice-skating and martial arts. However, the participant with the highest confidence score (80%) had very limited experience and indeed was an outlier (Stevens, 1984) in the association between confidence and COP. In older adults, over-confidence or a mismatch among balance confidence and performance or falls risk has been previously reported in up to 42% of the study sample (Fortinsky, Panzer, Wakefield, & Into, 2009; Medley & Thompson, 2015). Such high efficacy expectations can be developed based on other sources of information such as emotional arousal and vicarious experiences (Bandura, 1977). It appears BCS scores, however, may have been informed by previous experience with balance related activities, but not by general levels of physical activity.

Table 3
Experience with balance-related activities.

Participant codes	Activity (Skill level)	Confidence score (max. 100%)
P4ˆ	Skateboarding (B) Snowboarding (B)	79.63
P17	Muay thai (MS)	77.25
P20	Skiing (E) Ice skating (MS) Rollerblading (B)	74.13
P7	Ice skating (MS) Ballet and other dance forms (MS) Tai chi (B)	64.13
P13	Skateboarding (B) Snowboarding (B) Ice skating (B)	58.62
P10	Skiing (MS) Ice skating (B) Ballet and other dance forms (E)	58.50
P23	Snowboarding (MS) Rollerblading (MS) Biking (E)	58.38
P11	None	57.75
P21	Skiing (B) Ice skating (B) Slacklining (MS)	56.62
P9	Skateboarding (B) Ice skating (MS)	53.63
P12	Skateboarding (B)	52.25
P16	Skiing (B) Ice skating (B) Rollerblading (B) Slacklining (B)	48.00
P6	Skateboarding (MS) Skiing (MS) Ice skating (B)	45.25
P14	Snowboarding (B) Surfing (B)	45.13
P22	None	38.75
P24	None	37.13
P18	None	34.00

Note: Organized from highest to lowest Balance Confidence Scale scores.
B – beginner, MS – moderately skilled, E – elite.
ˆ outlier in validity analysis

Table 4
Correlations between Balance Confidence Scale scores and neural excitability.

	2WB	2NB	1Step	1Spring
Motor Evoked Potential	−0.26	−0.06	0.03	−0.15
Short Interval Intracortical Inhibition	0.28	0.00	0.18	**0.46*****
Intracortical Facilitation	**0.57***#**	0.31	0.07	0.03

Note: *Significant at $p < 0.05$, # indicates that one statistical outlier removed. 2WB, feet shoulder width apart, wide stance; 2NB, feet as close together as possible; narrow stance; 1Step, one foot on a solid block; 1Spring, one foot on an unstable spring.

4.4. Balance confidence and neural excitability

The correlational results of this study add confidence or self-efficacy to the list of cognitive or social-cognitive factors with associations to motor cortex activity, including a number that reflect outcome expectations (Kapogiannis, Campion, Grafman, & Wassermann, 2008; Thabit et al., 2011), observation of emotional attributes such as fear (Borgomaneri, Vitale, & Avenanti, 2017; Borgomaneri, Vitale, Gazzola, & Avenanti, 2015), and distinctions between task instructions emphasizing internal versus external foci of attention (Kuhn, Keller, Ruffieux, & Taube, 2017). The development of measures and methods to elucidate the mechanisms by which social-cognitive factors may influence the neural processes underlying production of optimal movement is of theoretical (Wulf & Lewthwaite, 2016) and practical significance.

The association with SICI in the present study emerged only in the most difficult test condition, suggesting that inhibition is coupled to confidence only when the task is sufficiently challenging. This finding is in line with the observation that confidence has a stronger relationship to performance in more difficult tasks (Reinhard & Dickhäuser, 2009; Themanson & Rosen, 2015). On the other hand, the association with ICF was observed in the easiest test condition. However, as task difficulty increased, greater ICF suppression was observed in more confident individuals, indicating that ICF may be affected by an interaction between confidence and task difficulty. In summary, we found that lower confidence was associated with lower M1 excitability with contributions from both inhibitory and facilitatory processes indexed using SICI and ICF respectively. Though fear and self-efficacy are somewhat independent constructs, low self-efficacy can increase fear (Bandura, 1986) and our findings are in line with the suppression of ICF during observation of fearful compared to neutral body postures (Borgomaneri et al., 2017, 2015). Additionally, when standing on higher relative to lower surfaces, both situation-specific confidence (Carpenter et al., 2006) and spinal excitability (H-reflex) are lower (Sibley, Carpenter, Perry, & Frank, 2007). This is in line with our findings of higher M1 inhibition and lower M1 facilitation in less confident individuals.

EEG studies suggest that TMS-evoked excitability, especially M1 facilitation, reflect inputs to the M1 from other brain areas (Di Lazzaro & Ziemann, 2013; Fedele et al., 2016; Ferreri et al., 2011) which could mediate the top-down influence of confidence. Additionally, enhanced expectancies may index anticipated reward that is associated with a dopaminergic response (Wulf & Lewthwaite, 2016). Dopaminergic neurons of the mesolimbic system, including those originating in the ventral tegmental area (VTA), are involved in encoding rewards. These neurons project to several frontal motor areas including M1 (Hosp, Pekanovic, Rioult-Pedotti, & Luft, 2011; Williams & Goldman-Rakic, 1993) and modulate the activity of both pyramidal neurons and inhibitory interneurons (Gao et al., 2013; Tseng et al., 2006). Other neurophysiological associates of confidence, including subcortical processes, may be observable using other methods (Meadows, Gable, Lohse, & Miller, 2016).

4.5. Balance confidence scale: potential applications and limitations

The broad range of BCS scores confirms that this questionnaire

Table 5
Correlations between Balance Confidence Scale scores and delta neural excitability.

	Δ 2NB-2WB	Δ 1Step-2WB	Δ 1Spring-2WB
Motor Evoked Potential	0.18	0.30	0.14
Short Interval Intracortical Inhibition	−0.43	−0.28	−0.21
Intracortical Facilitation#	−0.32	**−0.53***	**−0.71***

Note: *Significant at $p < 0.05$, # indicates that one statistical outlier removed. 2WB, feet shoulder width apart, wide stance; 2NB, feet as close together as possible; narrow stance; 1Step, one foot on a solid block; 1Spring, one foot on an unstable spring.

overcomes the problem of a ceiling effect observed when using currently available confidence measures in ostensibly healthy young adults. Additionally, the BCS is suitable for investigations using TMS in spatially constrained movements that nevertheless challenge balance. Optimal balance is foundational even in everyday activities and deficits in young adults may be exaggerated as they age. Future research might explore whether the BCS could be useful for identifying individuals at high risk of balance deterioration in order to implement early preventive interventions. The Balance Confidence Scale may also prove helpful in identifying athletes (professional and recreational) who may be experiencing a lack of psychological readiness to return to competition following an injury. Additionally, in young adults, confidence may influence not only performance, but also choices about participating in recreational activities, and consequently health and social outcomes. This preliminary study is limited to relatively small samples of healthy young adults. Future studies should examine athletes and individuals at risk for age-related deterioration in confidence and balance capabilities.

In this study, validity was tested by examining performance in conditions that were related but not identical to the test conditions. We believe that the demonstrated association between BCS scores and performance in a similar but different set of conditions, strengthens the case for the validity and utility of the BCS. Though the best estimates of confidence are likely condition specific, it is not possible, nor likely desirable, to obtain individual confidence estimates for the innumerable situations that can be encountered in 'real-world' scenarios and outside constrained laboratory settings. However, further validity testing using both laboratory-based and ecological performance measures can evaluate the generalizability of the scale.

5. Conclusions

The Balance Confidence Scale demonstrated good internal consistency and reliability, and preliminary validity. Additionally, BCS scores were correlated with balance performance and reflected the variation in previous experience with balance-related activities. Also, correlational analyses indicated that the effect of confidence on motor performance may be partially mediated though M1 excitability, particularly M1 facilitation, in similar task conditions.

Funding

None.

Disclosures

None.

Appendix. Balance Confidence Scale (BCS)

How confident are you that you can stay still for 1 min in each of the following conditions –

1. Standing on one leg, with eyes open and arms crossed across the chest

Not confident at all — Extremely confident

2. Standing on one leg, with eyes closed and arms crossed across the chest

Not confident at all — Extremely confident

3. Standing on one leg, with your heel off the floor, with eyes open and arms crossed across the chest

Not confident at all — Extremely confident

4. Standing on one leg, with your heel off the floor, with eyes closed and arms crossed across the chest

Not confident at all — Extremely confident

Questions 1 and 2

Questions 3 and 4

How confident are you that you can stay still for 1 min in each of the following conditions –

5. Standing on one leg, at the edge of a high block with eyes open and arms crossed across the chest

Not confident at all — Extremely confident

6. Standing on one leg, at the edge of a high block with eyes closed and arms crossed across the chest

Not confident at all — Extremely confident

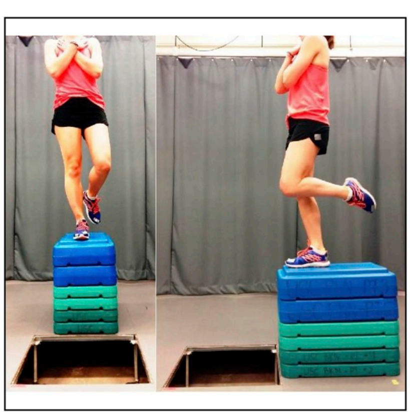
7. Standing on one leg, at the edge of a high block, with your heel off the floor, with eyes open and arms crossed across the chest

Not confident at all — Extremely confident

8. Standing on one leg, at the edge of a high block, with your heel off the floor, with eyes closed and arms crossed across the chest

Not confident at all — Extremely confident

Questions 5 and 6



Questions 7 and 8

References

Abbas, Z. A., & North, J. S. (2017). Good-vs. poor-trial feedback in motor learning: The role of self-efficacy and intrinsic motivation across levels of task difficulty. *Learning and Instruction*.

Arias, P., Robles-García, V., Espinosa, N., Corral-Bergantiños, Y., Mordillo-Mateos, L., Grieve, K., Oliviero, A., & Cudeiro, J. (2014). The effects of expectancy on corticospinal excitability: Passively preparing to observe a movement. *Journal of Neurophysiology, 111*(7), 1479–1486.

Asseman, F. B., Caron, O., & Crémieux, J. (2008). Are there specific conditions for which expertise in gymnastics could have an effect on postural control and performance? *Gait & Posture, 27*(1), 76–81.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191.

Bandura, A. (1986). *Fearful expectations and avoidant actions as coeffects of perceived self-inefficacy*.

Borgomaneri, S., Vitale, F., & Avenanti, A. (2017). Behavioral inhibition system sensitivity enhances motor cortex suppression when watching fearful body expressions. *Brain Structure and Function, 222*(7), 3267–3282.

Borgomaneri, S., Vitale, F., Gazzola, V., & Avenanti, A. (2015). Seeing fearful body language rapidly freezes the observer's motor cortex. *Cortex, 65*, 232–245.

Botner, E. M., Miller, W. C., & Eng, J. J. (2005). Measurement properties of the activities-specific balance confidence scale among individuals with stroke. *Disability & Rehabilitation, 27*(4), 156–163.

Bressel, E., Yonker, J. C., Kras, J., & Heath, E. M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training, 42*(1), 42.

Carpenter, M. G., Adkin, A. L., Brawley, L. R., & Frank, J. S. (2006). Postural, physiological and psychological reactions to challenging balance: Does age make a difference? *Age and Ageing, 35*(3), 298–303.

Cleworth, T. W., & Carpenter, M. G. (2016). Postural threat influences conscious perception of postural sway. *Neuroscience Letters, 620*, 127–131.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U. L. F., Yngve, A., Sallis, J. F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381–1395.

Di Lazzaro, V., & Ziemann, U. (2013). The contribution of transcranial magnetic stimulation in the functional evaluation of microcircuits in human motor cortex. *Frontiers in Neural Circuits*.

Fedele, T., Blagovechtchenski, E., Nazarova, M., Iscan, Z., Moiseeva, V., & Nikulin, V. V. (2016). Long-range temporal correlations in the amplitude of alpha oscillations predict and reflect strength of intracortical facilitation: Combined TMS and EEG study. *Neuroscience, 331*, 109–119.

Ferreri, F., Pasqualetti, P., Määttä, S., Ponzo, D., Ferrarelli, F., Tononi, G., Mervaala, E., Miniussi, C., & Rossini, P. M. (2011). Human brain connectivity during single and paired pulse transcranial magnetic stimulation. *NeuroImage, 54*(1), 90–102.

Fiorio, M., Emadi Andani, M., Marotta, A., Classen, J., & Tinazzi, M. (2014). Placebo-induced changes in excitatory and inhibitory corticospinal circuits during motor performance. *Journal of Neuroscience, 34*(11), 3993–4005.

Fortinsky, R. H., Panzer, V., Wakefield, D., & Into, F. (2009). Alignment between balance confidence and fall risk in later life: Has over-confidence been overlooked? *Health. Risk & Society, 11*(4), 341–352.

Gao, F., Edden, R. A. E., Li, M., Puts, N. A. J., Wang, G., Liu, C., Zhao, B., Wang, H., Bai, X., & Zhao, C. (2013). Edited magnetic resonance spectroscopy detects an age-related decline in brain GABA levels. *NeuroImage, 78*, 75–82.

Gao, K. L., Hui-Chan, C. W. Y., & Tsang, W. W. N. (2011). Golfers have better balance control and confidence than healthy controls. *European Journal of Applied Physiology, 111*(11), 2805–2812.

Gerbino, P. G., Griffin, E. D., & Zurakowski, D. (2007). Comparison of standing balance between female collegiate dancers and soccer players. *Gait & Posture, 26*(4), 501–507.

Gupta, N., & Aron, A. R. (2011). Urges for food and money spill over into motor system excitability before action is taken. *European Journal of Neuroscience, 33*(1), 183–188.

Hahn, T., Foldspang, A., Vestergaard, E., & Ingemann-Hansen, T. (1999). One-leg standing balance and sports activity. *Scandinavian Journal of Medicine & Science in Sports, 9*(1), 15–18.

Hatch, J., Gill-Body, K. M., & Portney, L. G. (2003). Determinants of balance confidence in community-dwelling elderly people. *Physical Therapy, 83*(12), 1072–1079 8p.

Hebbal, G. V., & Mysorekar, V. R. (2006). Evaluation of some tasks used for specifying handedness and footedness. *Perceptual & Motor Skills, 102*(1), 163–164.

Hosp, J. A., Pekanovic, A., Rioult-Pedotti, M. S., & Luft, A. R. (2011). Dopaminergic projections from midbrain to primary motor cortex mediate motor skill learning. *Journal of Neuroscience, 31*(7), 2481–2487.

Hutchinson, J. C., Sherman, T., Martinovic, N., & Tenenbaum, G. (2008). The effect of manipulated self-efficacy on perceived and sustained effort. *Journal of Applied Sport Psychology, 20*(4), 457–472.

Kapogiannis, D., Campion, P., Grafman, J., & Wassermann, E. M. (2008). Reward-related activity in the human motor cortex. *European Journal of Neuroscience, 27*(7), 1836–1842.

Kiers, H., van Dieën, J., Dekkers, H., Wittink, H., & Vanhees, L. (2013). A systematic review of the relationship between physical activities in sports or daily life and postural sway in upright stance. *Sports Medicine, 43*(11), 1171–1189.

Klein, P.-A., Olivier, E., & Duque, J. (2012). Influence of reward on corticospinal excitability during movement preparation. *Journal of Neuroscience, 32*(50), 18124–18136.

Kuhn, Y., Keller, M., Ruffieux, J., & Taube, W. (2017). Adopting an external focus of attention alters intracortical inhibition within the primary motor cortex. *Acta Physiologica, 220*(2), 289–299.

Lamarche, L., Shaw, J. A., Gammage, K. L., & Adkin, A. L. (2009). Manipulating balance perceptions in healthy young adults. *Gait & Posture, 29*(3), 383–386.

Lemos, T., Imbiriba, L. A., Vargas, C. D., & Vieira, T. M. (2015). Modulation of tibialis anterior muscle activity changes with upright stance width. *Journal of Electromyography and Kinesiology, 25*(1), 168–174.

Lin, D., Seol, H., Nussbaum, M. A., & Madigan, M. L. (2008). Reliability of COP-based postural sway measures and age-related differences. *Gait & Posture, 28*(2), 337–342.

McAuley, E., & Gill, D. (1983). Reliability and validity of the physical self-efficacy scale in a competitive sport setting. *Journal of Sport Psychology, 5*(4), 410–418.

Mcguine, T. A., Greene, J. J., Best, T., & Leverson, G. (2000). Balance as a predictor of ankle injuries in high school basketball players. *Clinical Journal of Sport Medicine, 10*(4), 239–244.

McKay, B., Lewthwaite, R., & Wulf, G. (2012). Enhanced expectancies improve performance under pressure. *Frontiers in Psychology, 3*.

McKeon, P. O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part I: Can deficits be detected with instrumented testing? *Journal of Athletic Training, 43*(3), 293–304.

Meadows, C. C., Gable, P. A., Lohse, K. R., & Miller, M. W. (2016). Motivation and motor cortical activity can independently affect motor performance. *Neuroscience, 339*, 174–179.

Medley, A., & Thompson, M. (2015). Contribution of age and balance confidence to functional mobility test performance: Diagnostic accuracy of L test and normal-paced timed up and go. *Journal of Geriatric Physical Therapy, 38*(1), 8–16.

Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: A comparison between fallers and non-fallers. *Age and Ageing, 33*(6), 602–607.

Mooshagian, E., Keisler, A., Zimmermann, T., Schweickert, J. M., & Wassermann, E. M. (2015). Modulation of corticospinal excitability by reward depends on task framing. *Neuropsychologia, 68*, 31–37.

Moritz, S. E., Feltz, D. L., Fahrbach, K. R., & Mack, D. E. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise & Sport, 71*(3), 280–294.

Motl, R. W., Konopack, J. F., Hu, L., & McAuley, E. (2006). Does self-efficacy influence leg muscle pain during cycling exercise? *The Journal of Pain, 7*(5), 301–307.

Myers, A. M., Powell, L. E., Maki, B. E., Holliday, P. J., Brawley, L. R., & Sherk, W. (1996). Psychological indicators of balance confidence: Relationship to actual and perceived abilities. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 51A*(1), M37–M43.

Nandi, T., Fisher, B. E., Hortobágyi, T., & Salem, G. J. (2018). Increasing mediolateral standing sway is associated with increasing corticospinal excitability, and decreasing M1 inhibition and facilitation. *Gait & Posture, 60*, 135–140.

Nandi, T., Lamoth, C. J. C., van Keeken, H. G., Bakker, L. B. M., Kok, I., Salem, G. J., Fisher, B. E., & Hortobágyi, T. (2018). Standing, corticospinal excitability is proportional to COP velocity whereas M1 excitability is participant-specific. *Frontiers in Human Neuroscience, 12*.

Nilsson, G., Ageberg, E., Ekdahl, C., & Eneroth, M. (2006). Balance in single-limb stance after surgically treated ankle fractures: A 14-month follow-up. *BMC Musculoskeletal Disorders, 7*(1), 35.

Paillard, T., Noe, F., Riviere, T., Marion, V., Montoya, R., & Dupui, P. (2006). Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. *Journal of Athletic Training, 41*(2), 172.

Papegaaij, S., Baudry, S., Négyesi, J., Taube, W., & Hortobágyi, T. (2016). Intracortical inhibition in the soleus muscle is reduced during the control of upright standing in both young and old adults. *European Journal of Applied Physiology, 116*(5), 959–967.

Papegaaij, S., Taube, W., Hogenhout, M., Baudry, S., & Hortobágyi, T. (2014). Age-related decrease in motor cortical inhibition during standing under different sensory conditions. *Frontiers in Aging Neuroscience, 6*(June), 126.

Piirtola, M., & Era, P. (2006). Force platform measurements as predictors of falls among older people - a review. *Gerontology, 52*(1), 1–16.

Prieto, T. E., Myklebust, J. B., Hoffmann, R. G., Lovett, E. G., & Myklebust, B. M. (1996). Measures of postural steadiness: Differences between healthy young and elderly adults. *IEEE Transactions on Biomedical Engineering, 43*(9), 956–966.

Reinhard, M.-A., & Dickhäuser, O. (2009). Need for cognition, task difficulty, and the formation of performance expectancies. *Journal of Personality and Social Psychology, 96*(5), 1062.

Rudolph, D. L., & McAuley, E. (1996). Self-efficacy and perceptions of effort: A reciprocal relationship. *Journal of Sport & Exercise Psychology, 18*(2), 216–223.

Ruhe, A., Fejer, R., & Walker, B. (2010). The test-retest reliability of centre of pressure measures in bipedal static task conditions - a systematic review of the literature. *Gait & Posture, 32*, 436–445.

Schepens, S., Goldberg, A., & Wallace, M. (2010). The short version of the activities-specific balance confidence (ABC) scale: Its validity, reliability, and relationship to balance impairment and falls in older adults. *Archives of Gerontology and Geriatrics, 51*(1), 9–12.

Schieppati, M., Tacchini, E., Nardone, A., Tarantola, J., & Corna, S. (1999). Subjective perception of body sway. *Journal of Neurology, Neurosurgery, and Psychiatry, 66*(3), 313–322.

Sibley, K. M., Carpenter, M. G., Perry, J. C., & Frank, J. S. (2007). Effects of postural anxiety on the soleus H-reflex. *Human Movement Science, 26*(1), 103–112.

Sozzi, S., Honeine, J. L., Do, M. C., & Schieppati, M. (2013). Leg muscle activity during tandem stance and the control of body balance in the frontal plane. *Clinical Neurophysiology, 124*(6), 1175–1186.

Stevens, J. P. (1984). Outliers and influential data points in regression analysis. *Psychological Bulletin, 95*(2), 334.

Talley, K. M. C., Wyman, J. F., & Gross, C. R. (2008). Psychometric properties of the activities-specific balance confidence scale and the survey of activities and fear of falling in older women. *Journal of the American Geriatrics Society, 56*(2), 328–333.

Thabit, M. N., Nakatsuka, M., Koganemaru, S., Fawi, G., Fukuyama, H., & Mima, T. (2011). Momentary reward induce changes in excitability of primary motor cortex. *Clinical Neurophysiology, 122*(9), 1764–1770.

Themanson, J. R., Hillman, C. H., McAuley, E., Buck, S. M., Doerksen, S. E., Morris, K. S., & Pontifex, M. B. (2008). Self-efficacy effects on neuroelectric and behavioral indices of action monitoring in older adults. *Neurobiology of Aging, 29*(7), 1111–1122.

Themanson, J. R., & Rosen, P. J. (2015). Examining the relationships between self-efficacy, task-relevant attentional control, and task performance: Evidence from event-related brain potentials. *British Journal of Psychology, 106*(2), 253–271.

Trojian, T. H., & McKeag, D. B. (2006). Single leg balance test to identify risk of ankle sprains. *British Journal of Sports Medicine, 40*(7), 610–613.

Tropp, H., Ekstrand, J., & Gillquist, J. (1984). Stabilometry in functional instability of the ankle and its value in predicting injury. *Medicine & Science in Sports & Exercise, 16*(1), 64–66.

Tropp, H., & Odenrick, P. (1988). Postural control in single-limb stance. *Journal of Orthopaedic Research, 6*(6), 833–839.

Tseng, K. Y., Mallet, N., Toreson, K. L., Le Moine, C., Gonon, F., & O'Donnell, P. (2006). Excitatory response of prefrontal cortical fast-spiking interneurons to ventral tegmental area stimulation in vivo. *Synapse, 59*(7), 412–417.

Vuillerme, N., Danion, F., Marin, L., Boyadjian, A., Prieur, J. M., Weise, I., & Nougier, V. (2001). The effect of expertise in gymnastics on postural control. *Neuroscience Letters, 303*(2), 83–86.

Weiss, M. R., Wiese, D. M., & Klint, K. A. (1989). Head over heels with success: The relationship between self-efficacy and performance in competitive youth gymnastics. *Journal of Sport & Exercise Psychology, 11*(4), 444–451.

Williams, S. M., & Goldman-Rakic, P. S. (1993). Characterization of the dopaminergic innervation of the primate frontal cortex using a dopamine-specific antibody. *Cerebral Cortex, 3*(3), 199–222.

Winter, D. A., Prince, F., Frank, J. S., Powell, C., & Zabjek, K. F. (1996). Unified theory regarding A/P and M/L balance in quiet stance. *Journal of Neurophysiology, 75*(6), 2334–2343.

Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sport performance: A meta-analysis. *Journal of Sports Sciences, 21*(6), 443–457.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin & Review, 23*(5), 1382–1414.