Neural control of balance in increasingly difficult standing tasks

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Assessing balance confidence in young adults

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Psychology of Sport and Exercise (Under Review)
ABSTRACT

The authors developed a Standing Balance Confidence (SBC) questionnaire for healthy young adults, comprised of items depicting single limb stance conditions of varying difficulty. Preliminary SBC validity was examined relative to balance performance, perceived steadiness, and previous physical activity. SBC scores showed good internal consistency (Cronbach’s $\alpha = 0.81$) and high test-retest reliability (ICC = 0.92). SBC scores were 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. Perceived steadiness and overall physical activity were not correlated with confidence. However, participants with higher SBC scores reported greater experience with balance-related activities. Finally, correlational analyses indicated that the effect of confidence on motor performance may be partially mediated through motor cortical excitability.
1. INTRODUCTION

Optimal standing 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 sport performance [1] and injury risk [2]. Self-efficacy, the sense that one can successfully execute the actions or behavior required to produce outcomes [3], often considered task-specific confidence, is known to be related to motor performance [4–7]. Specifically, balance confidence has been related to postural sway and falls, as well as athletic performance [8–14]. Currently available measures, such as the Activities-specific Balance Confidence (ABC) scale are designed to assess balance confidence in a range of everyday activities in older adults and individuals with conditions such as amputation and stroke [11,15], and a ceiling effect is encountered when examining ostensibly healthy or skilled populations. Therefore, our primary aim was to design a Standing Balance Confidence questionnaire (SBC) relevant to healthy young adults, and to examine evidence related to its preliminary reliability and validity.

The SBC questionnaire 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 and reaching to a high shelf. Additionally, SLS stability remains impaired for more than a year after ankle surgery [16], can distinguish individuals with ankle instability [17], and is predictive of injuries [18–20]. Further, greater SLS stability is observed in more experienced athletes [21,22] and athletes engaged in activities such as dance and gymnastics that specifically challenge balance [23–26]. Both theoretical [3] and behavioral observations [27–29] suggest that confidence has a greater influence on motor performance when task difficulty is at least moderately high. Therefore, the SBC included items that depicted variations in standing task difficulty, including removal of visual input, restriction of the base of support (BOS), and/or increased surface height [30–33]

Construct validity was evaluated by examining the relations between confidence and balance performance, quantified using center of pressure (COP) (e.g., [11]). Additionally, we examined whether individuals’ perceptions of their steadiness and their confidence regarding future balancing capabilities were related. COP dynamics and perceived steadiness 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 use of unstable surfaces. Finally, since confidence is expected to be influenced by previous experiences, we include a self-reported general physical activity score and a qualitative assessment regarding participants’ experience with athletic activities that challenge balance.
Balance confidence is a particular case of expectancies which refer to anticipatory or predictive beliefs or cognitions about what is to occur, and may index future rewarding experiences or outcomes [7]. There is growing interest in understanding the underlying neural mechanisms through which expectancies may shape motor output, and consequently performance [7,29,34–40]. Using transcranial magnetic stimulation (TMS), both corticospinal excitability (CSE) and primary motor cortex (M1) excitability 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 pill) will lead to certain outcomes (e.g., well-being). However, neural excitability has not been examined in relation to personal performance expectations or confidence. Therefore, our secondary aim was to examine the association between confidence and neural excitability in the aforementioned test conditions. TMS was used to quantify motor evoked potential (MEP) amplitude, short interval intra-cortical inhibition (SICI), and intra-cortical facilitation (ICF) which index CSE, M1 inhibition and M1 facilitation, respectively.

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 SBC validity and neural excitability were tested (Nandi, Fisher, Hortobágyi, & Salem, 2018). Another 6 participants completed the SBC 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 SBC. Subsequently, force plate and TMS data were collected in the four physical test conditions.

2.2.1. Standing Balance Confidence questionnaire
Participants completed the SBC in which they were asked to rate how confident they were that they could stay still for 1 minute under each photographically depicted posture (see Appendix). 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 (max. 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. Six participants repeated the questionnaire a week later 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

**Balance performance: Center of pressure**

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). Participants completed 4 test conditions: 1) feet shoulder width apart (i.e., wide stance; 2WB); 2) feet as close together as possible (i.e., narrow stance; 2NB); 3) one foot on a solid block (1Step), ~30 cm high; and 4), and 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 [41] 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’.

COP data were filtered using a 4th order low pass Butterworth filter with a 10 Hz cut off. COP velocity was calculated in a 2s window before application of the TMS pulse. Values were averaged over 30 trials (see neural excitability methods below) to obtain a single estimate for each test condition.

**Perceived steadiness**

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’ [33]. The question was asked immediately after the participants practiced each test condition.

**Previous experiences**

The self-report International Physical Activity Questionnaire (IPAQ) [42] was used to quantify general physical activity history in metabolic equivalents (METs). Additionally, participants were asked about experience, during the last 5 years, with the following balance related activities: skateboarding, skiing, snowboarding, ice skating, rollerblading, slacklining, bal-
let 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 [43]. 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) electrode (inter electrode distance 17 mm, Motion Lab Systems, Baton Rouge, LA). EMG data were acquired at 15000 Hz and stored using Signal software (v6, Cambridge Electronic Design Ltd, Cambridge UK). The tibialis anterior (TA), a primary ankle invertor, was tested because it plays an important role in maintaining balance, especially when BOS decreases [44–46]. 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 [47]. MEPs obtained using a single pulse are an index of CSE. 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 pulses.

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 3ms and 13ms ISI double pulse trials respectively.

1. **SICI** = (ConditionedSICI/Test MEP \*100); smaller values indicate greater inhibition.
2. **ICF** = (ConditionedICF/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 used to test for associations between confidence and COP velocity, perceived steadiness, and IPAQ scores. Correlation between confidence and perceived steadiness was examined using data pooled data across all 4 test conditions [33]. 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 tested. Significance level was set at 0.05. Using the Shapiro-Wilk test it was found that the variables were not normally distributed in one or more conditions. Spearman correlation coefficients were computed for these conditions.

3. RESULTS

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

Total Standing Balance Confidence scores ranged from 34 to 79.6% (56±12.5%). Good internal consistency was confirmed by a Cronbach’s $\alpha$ 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 SBC had high test-retest reliability with an ICC$_{2,1}$ of 0.92.

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean (%)</th>
<th>[standard deviation]</th>
</tr>
</thead>
<tbody>
<tr>
<td>“How confident are you that you can stay still for 1 minute in each of the following conditions:”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLS, with eyes open and arms crossed across the chest</td>
<td>84.7</td>
<td>[13.6]</td>
</tr>
<tr>
<td>SLS, at the edge of a high block with eyes open and arms crossed across the chest</td>
<td>74.0</td>
<td>[19.0]</td>
</tr>
<tr>
<td>SLS, with small BOS, with eyes open and arms crossed across the chest</td>
<td>62.0</td>
<td>[20.0]</td>
</tr>
<tr>
<td>SLS, with eyes closed and arms crossed across the chest</td>
<td>60.8</td>
<td>[18.0]</td>
</tr>
<tr>
<td>SLS, at the edge of a high block, with small BOS, with eyes open and arms crossed across the chest</td>
<td>51.0</td>
<td>[24.0]</td>
</tr>
<tr>
<td>SLS, at the edge of a high block with eyes closed and arms crossed across the chest</td>
<td>48.7</td>
<td>[17.9]</td>
</tr>
<tr>
<td>SLS, with small BOS, with eyes closed and arms crossed across the chest</td>
<td>38.4</td>
<td>[19.3]</td>
</tr>
<tr>
<td>SLS, at the edge of a high block, with small BOS, with eyes closed and arms crossed across the chest</td>
<td>28.3</td>
<td>[19.0]</td>
</tr>
<tr>
<td>Standing balance confidence scale total score</td>
<td>56</td>
<td>[12.5]</td>
</tr>
</tbody>
</table>

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
3.2. Construct validity

**Balance performance: Center of pressure**

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), after removal of one statistical outlier (Cook’s d > 1 [48]).

<table>
<thead>
<tr>
<th></th>
<th>2WB</th>
<th>2NB</th>
<th>1Step</th>
<th>1Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>COP velocity</td>
<td>0.15</td>
<td>-0.05</td>
<td>-0.09</td>
<td>-0.62*#</td>
</tr>
<tr>
<td>COP area</td>
<td>0.15</td>
<td>-0.02</td>
<td>0.06</td>
<td>-0.49*#</td>
</tr>
</tbody>
</table>

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

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

**Perceived steadiness**

Perceived steadiness, assessed regarding the last trial in each test condition, was not correlated with confidence. However, a significant negative correlation was found between perceived steadiness and COP velocity \( (r = -0.68, p < 0.001) \) and area \( (r = -0.53, p < 0.001) \).
Previous experiences

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.

Table 3 Experience with balance-related activities

<table>
<thead>
<tr>
<th>Participant codes</th>
<th>Activity (skill level)</th>
<th>Confidence score (max. 100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4^</td>
<td>Skateboarding (B)</td>
<td>79.63</td>
</tr>
<tr>
<td></td>
<td>Snowboarding (B)</td>
<td></td>
</tr>
<tr>
<td>P17</td>
<td>Muay thai (MS)</td>
<td>77.25</td>
</tr>
<tr>
<td>P20</td>
<td>Skiing (E)</td>
<td>74.13</td>
</tr>
<tr>
<td></td>
<td>Ice skating (MS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rollerblading (B)</td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>Ice skating (MS)</td>
<td>64.13</td>
</tr>
<tr>
<td></td>
<td>Ballet and other dance forms (MS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tai chi (B)</td>
<td></td>
</tr>
<tr>
<td>P13</td>
<td>Skateboarding (B)</td>
<td>58.62</td>
</tr>
<tr>
<td></td>
<td>Snowboarding (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ice skating (B)</td>
<td></td>
</tr>
<tr>
<td>P10</td>
<td>Skiing (MS)</td>
<td>58.50</td>
</tr>
<tr>
<td></td>
<td>Ice skating (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ballet and other dance forms (E)</td>
<td></td>
</tr>
<tr>
<td>P23</td>
<td>Snowboarding (MS)</td>
<td>58.38</td>
</tr>
<tr>
<td></td>
<td>Rollerblading (MS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biking (E)</td>
<td></td>
</tr>
<tr>
<td>P11</td>
<td>None</td>
<td>57.75</td>
</tr>
<tr>
<td>P21</td>
<td>Skiing (B)</td>
<td>56.62</td>
</tr>
<tr>
<td></td>
<td>Ice skating (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slacklining (MS)</td>
<td></td>
</tr>
<tr>
<td>P9</td>
<td>Skateboarding (B)</td>
<td>53.63</td>
</tr>
<tr>
<td></td>
<td>Ice skating (MS)</td>
<td></td>
</tr>
<tr>
<td>P12</td>
<td>Skateboarding (B)</td>
<td>52.25</td>
</tr>
<tr>
<td>P16</td>
<td>Skiing (B)</td>
<td>48.00</td>
</tr>
<tr>
<td></td>
<td>Ice skating (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rollerblading (B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slacklining (B)</td>
<td></td>
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<tr>
<td>P6</td>
<td>Skateboarding (MS)</td>
<td>45.25</td>
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<tr>
<td></td>
<td>Skiing (MS)</td>
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</tr>
<tr>
<td></td>
<td>Ice skating (B)</td>
<td></td>
</tr>
<tr>
<td>P14</td>
<td>Snowboarding (B)</td>
<td>45.13</td>
</tr>
<tr>
<td></td>
<td>Surfing (B)</td>
<td></td>
</tr>
<tr>
<td>P22</td>
<td>None</td>
<td>38.75</td>
</tr>
<tr>
<td>P24</td>
<td>None</td>
<td>37.13</td>
</tr>
<tr>
<td>P18</td>
<td>None</td>
<td>34.00</td>
</tr>
</tbody>
</table>

Organized from highest to lowest SBC score. Participants with the highest and lowest SBC scores i.e., >1SD higher or lower than mean, are highlighted in green and red respectively.
B – Beginner, MS – moderately skilled, E – Elite
^ outlier in validity analysis
3.3. Neural excitability

**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 [48]) (Table 4). Confidence was not correlated with MEP in any condition.

<table>
<thead>
<tr>
<th>Table 4 Correlations between SBC scores and neural excitability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>Motor evoked potential</td>
</tr>
<tr>
<td>Short interval intracortical inhibition</td>
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<tr>
<td>Intracortical facilitation</td>
</tr>
</tbody>
</table>

*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.

**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.

<table>
<thead>
<tr>
<th>Table 5 Correlations between SBC scores and delta neural excitability</th>
</tr>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Motor evoked potential</td>
</tr>
<tr>
<td>Short interval intracortical inhibition</td>
</tr>
<tr>
<td>Intracortical facilitation#</td>
</tr>
</tbody>
</table>

*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. DISCUSSION

The primary aim of this study was to test preliminary reliability and construct validity of the SBC questionnaire 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 SBC questionnaire is suitable for this population and may not suffer from the ceiling effects expected in other measures. We
found good internal consistency and high test-retest reliability over a one-week interval, but confidence 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 [11]. Confidence scores were not correlated with perceived steadiness and generic physical activity scores. However, participants with higher SBC 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 [49–51].

4.1. Construct validity

**Construct validity: Balance performance**
COP dynamics reflect the net neuromuscular response that controls spontaneous postural sway in standing [46]. COP measurements are reliable, can consistently discriminate between different postures and populations, and are predictive of falls [52–55]. 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 [32]. In line with this, 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.

**Construct validity: Perceived steadiness**
Based on self-efficacy theory, it is hypothesized that confidence can influence perceptions of success and/or performance [56]. For instance, high confidence is associated with both better performance and lower perceived exertion during an endurance task [57,58]. 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, are independent of each other [31,59]. 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. Indeed, in agreement with previous findings, we found that individuals’ perceptions of sway are reasonably accurate and match with objectively quantified sway [33].
Construct validity: Previous experiences

Bandura postulated that previous experiences and performance accomplishments are a major source of efficacy information [3]. 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 SBC, SLS, visual feedback deprivation and BOS restrictions are components of many complex movements required to accomplish daily activities. For instance, reaching to a high shelf may require standing on one leg and balancing on a BOS limited to the toes. 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 [48] in the association between confidence and COP. In older adults, over-confidence or a mismatch between balance confidence and performance or falls risk has been previously reported in up to 42% of the study sample [60,61]. Such high efficacy expectations can be developed based on other sources of information such as emotional arousal and vicarious experiences [3]. However, SBC scores may have been informed by previous experience with balance related activities, but not by general levels of physical activity.

4.2. Balance confidence and neural excitability

The correlational results of this study add confidence or self-efficacy to the list of cognitive factors with associations to motor cortex activity, including a number that reflect outcome expectations [39,62], observation of emotional attributes such as fear [63,64], and distinctions between task instructions emphasizing internal versus external foci of attention [65]. 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 [28,29]. 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 is affected by an interaction between confidence and task difficulty. In summary, we found that lower confidence is associated with lower M1 excitability with contributions from both GABAergic and glutamatergic processes indexed using SICI and ICF respectively. Though fear and self-efficacy are independent constructs, low self-efficacy can increase
fear [66] and our findings are in line with the suppression of ICF during observation of fearful compared to neutral body postures [63,64]. Additionally, when standing on high relative to low surfaces, both situation-specific confidence [30] and spinal excitability (H-reflex) are lower [67]. 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 [49–51] which could mediate the top-down influence of confidence. Additionally, enhanced expectancies may index anticipated reward that is associated with a dopaminergic response [7]. 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 [68,69] and modulate the activity of both pyramidal neurons and inhibitory interneurons [70,71]. Other neurophysiological associates of confidence, including subcortical processes, may be observable using other methods [72].

5. CONCLUSIONS

The SBC questionnaire demonstrated high internal consistency and reliability, and preliminary validity. A large range of scores was observed in a sample of ostensibly healthy young adults and the potential for this instrument to detect situations including, for example, lack of psychological readiness to return to competition in injured athletes, deserves future research attention. Additionally, SBC 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.
6. REFERENCES


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


APPENDIX: STANDING BALANCE CONFIDENCE (SBC) SCALE

How confident are you that you can stay still for 1 minute 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 minute 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]