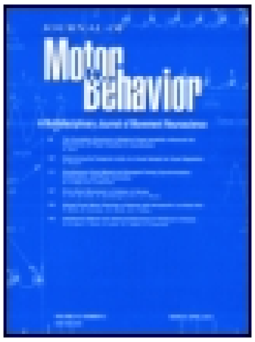

Journal of Motor Behavior

ISSN: 0022-2895 (Print) 1940-1027 (Online) Journal homepage: http://www.tandfonline.com/loi/vjmb20

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To cite this article: Megan A. Bryanton & Martin Bilodeau (2018): The Effect of Vision and Surface Compliance on Balance in Untrained and Strength Athletes, Journal of Motor Behavior, DOI: 10.1080/00222895.2017.1423019

To link to this article: https://doi.org/10.1080/00222895.2017.1423019

Journal of Motor Behavior, Vol. 0, No. 0, 2018

RESEARCH ARTICLE

The Effect of Vision and Surface Compliance on Balance in Untrained and Strength Athletes

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ABSTRACT. The purpose of this investigation was to evaluate the effect of the removal of vision and/or surface compliance on postural stability in strength athletes who habitually use free-weights and compound movements in their training (i.e., powerlifters, Olympic weightlifters), and untrained individuals. Static and dynamic balance testing was performed with eyes open or closed on stable and memory foam surfaces. Both groups had similar increases in postural sway area and velocity during quiet standing testing; whereas group main effects and interactions for dynamic testing revealed that untrained participants experienced greater relative declines in postural performance when voluntary limits of stability are stressed, especially when both vision and surface compliance were deterred. These results demonstrate that in comparison to untrained young adults, postural control variables may be reduced to a lesser extent in strength athletes when sensory constraints are altered; however this appears to be specific to the type of postural task performed.

Keywords: posture, somatosensory, vision, weight training

INTRODUCTION

The control balance requires the development of appropriate muscular efforts in a controlled and coordinated fashion to prevent the vertical projection of center of mass (COM) from deviating outside of postural boundary limits. This is essential in response to natural oscillations in body sway, large vertical/horizontal displacements of COM during dynamic movement, as well as unexpected postural perturbations (Błaszczyk, Cieślinska-Świder, Plewa, Zahorska-Markiewicz, & Markiewicz, 2009; Corbeil, Simoneau, Rancourt, Tremblay, & Teasdale, 2001; Pai & Patton, 1997; Shumway-Cook & Woollacott, 1995). The ability to sense body orientation within the environment is essential for this control of balance, as afferent input obtained from the visual, vestibular, and somatosensory systems provide the necessary information to maintain body posture via muscle activation (Speers, Kuo, & Horak, 2002; Sturnieks, St George, & Lord, 2008). Somatosensory input relays essential information to the central nervous system (CNS) from sensory receptors located in the skin, muscles, tendons, and joints regarding the position of body segments relative to each other in space (Horak & Nashner, 1986; Speers et al., 2002; Sturnieks et al., 2008; Yim-Chiplis & Talbot, 2000). Depending on environmental constraints, such as instances of compromised somatosensory input, the CNS must adaptively increase the sensory gain of alternative afferent sources in order to maintain postural stability (Horak & Nashner, 1986). In turn, the ability to adapt to altering sensory conditions would reflect greater balance control capabilities, and has been shown to be an indication of whether an individual is at an increased risk of falling (Speers et al., 2002; Teasedale & Simoneau, 2001).

With balance training, the repetition of a specific multiarticular movement through practice has been previously shown to induce postural adaptations through better use of somatosensory information, and as a result, more effective motor planning and output (Lee & Lishman, 1975; Maitre, J., Serres, I., Lhuisset, L., Bois, J., Gasnier, Y., & Paillard, T., 2015). Additionally, previous investigations have shown that in motor-impaired populations, even greater improvements in postural stability are achieved with the addition of resistance training to balance training programs, than balance training alone (Hirsch, Toole, Maitland, & Rider, 2003; Joshua, A. M., D'Souza, V., Unnikrishnan, B., Mithra, P., Kamath, A., Acharya, V., & Venugopal, A., 2014). Resistance training has been shown to be an effective means of increasing muscular strength and hypertrophy, as well as induce adaptations specific to the recruitment of muscles involved in the trained task (Carroll, Riek, & Carson, 2001; Sale, 1988); however, training adaptations associated with sensorimotor components of balance control is less considered. Moreover, static evaluations of balance do not appear to be reflective of dynamic performance values in athletes, and have been found to differ between athletes of different sport, as well as competitive level (Bressel, Yonker, Kras, & Heath, 2007; Davlin, 2004; Hrysomallis, 2011; Hrysomallis, McLaughlin, & Goodman, 2006). These findings may, therefore, be reflective of the physical demands of the sport, type of training program, and training experience of the individual athlete.

The addition of external loading with the use of free-weights during resistance training would impose greater mechanical demands on the body due to the COM of the total system being further away (higher) from the axis of

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rotation (joint motion). Resultant increases in gravitational torques to accelerate the body must, in turn, be accurately controlled by larger muscular torques in order to prevent loss of balance, and in turn challenge postural stability (Corbeil et al., 2001; Granacher & Gollhofer, 2011). This is supported by investigations which have shown reduced postural stability when individuals are subjected to additional body loading or have excessive body weights (Błaszczyk et al., 2009; Heller, Challis, & Sharkey, 2009). For example, Heller et al., (2009) found that when female participants were asked to wear military backpacks of an additional 18.1 kg of external weight, center of pressure (COP) path excursions increased substantially. The added mass about the torso and new biomechanical constraints imposed on the individuals would therefore alter the muscular demands of the task in order to accurately control vertical projections of COM within the base of support (Helleret al., 2009; Rosker, Markovic, & Sarabon, 2011). Considering this, it is hypothesized that balance would be challenged like this on a regular basis for individuals who participate in barbell weight training exercises, as there is a greater need to control the position of the combined COM of the body and barbell loading (Corbeil et al., 2001; Flanagan & Salem, 2008; Rosker et al., 2011; Sato & Heise, 2012).

If training adaptations are task specific, strength athletes such as powerlifters and Olympic weightlifters whose sports revolve around the use of barbell weighted training, may develop skillful control of body posture via contraction of large agonist and stabilizing muscle groups. In turn, this may improve their ability to control their COP about the base of support. Secondly, since dynamic tasks such as those during free-weight training require large joint rotations and displacements of COM (Granacher & Gollhofer, 2011), static balance measures may not be challenging or specific enough to reveal difference between strength-trained and untrained individuals. Therefore, the objective of this investigation was to compare the extent to which both static and dynamic balance performance is compromised when visual and/or somatosensory input (i.e., surface compliance) is altered in habitually strength-trained athletes and untrained individuals.

METHODS

PARTICIPANTS

Seven strength-trained and nine untrained young adults between the ages of 18–30 with no balance impairments were recruited to participate in this investigation (Table 1). The strength-trained group was comprised of National level competitive strength athletes (Powerlifting, Olympic Weightlifting) who train for their respective sport using barbell free-weights for a minimum of three times per week, with a minimum of three years of consistent resistance training experience. The untrained group included healthy individuals recruited with no current or prior resistance free-weight training experience. Age, body weight (kg), and height (cm) were collected for each participant along with anthropometric data of total foot length (heel to distal end of second toe) for both left and right feet. The study was approved under the Bruyère Continuing Care and the University of Ottawa Institutional Review Boards and prior to testing written informed consent was obtained from each participant.

TABLE 1. Group mean (±SD) subject characteristics.

Group	Age (yrs)	Height (cm)	Bodyweight (kg)	Foot length (cm)
Strength trained	27.1 (2.6)	171.0 (10.6)	82.9 (23.6)	24.9 (2.0)
Untrained	23.9 (1.9)	169.5 (13.2)	74.0 (13.1)	25.6 (2.9)

PROCEDURES

QUIET STANDING

Static postural testing was performed while standing on an AMTI Acu-Gait force platform (Watertown, MA), from which COP data were collected at a sampling rate of 100 Hz. Participants stood barefoot with feet together in a relaxed upright position on the force platform. For each trial, participants were asked to stand quietly for 30 seconds. This task was performed with their eyes-open (EO) and eyes-closed (EC) (i.e., two visual conditions), on both stable (S) and compliant memory foam (F) surfaces (i.e., two somatosensory conditions), for a total of four sensory conditions; EO-S, EC-S, EO-F, EC-F. Three trials were performed for each of the four sensory conditions, in a randomized order. COP data were collected using Net-Force v. 2.3.0 (AMTI's Biomechanics Software). Sway area (cm^2), defined by the area of the 95th percentile ellipse (which estimates area of COP movement over the test duration with a 95% confidence interval), as well as sway velocity (total COP path length over trial time, cm/s), was calculated using BioAnalysis 2.3.0 software (Watertown, MA). One minute of rest was provided between each trial in order to minimize the effects of fatigue.

VOLUNTARY LIMITS OF STABILITY

Similar to quiet standing testing, participants were again asked to stand barefoot with their feet together on a force platform. During each trial, they were instructed to first shift their weight forward toward their toes as far as they could without falling, and then backwards toward their heels over the largest possible amplitude while maintaining full contact between their feet and the force platform. Additionally, once participants believed that they reached their maximum lean position in either direction, they were asked to hold that position as stably as possible for 10 seconds. They were instructed to keep their knees and hips in relaxed neutral alignment (Błaszczyk et al., 2009). The trials were repeated three times for each of the four previously described sensory conditions (EO-S, EO-F, EC-S, and EC-F) in a randomized order. Data analyses involved calculations of anteroposterior dynamic range (the range between maximum anterior and posterior COP excursions normalized with respect to total foot length; %). Sway velocity was also calculated during the 10 second lean hold times and averaged between anterior and posterior directions as a measure of their ability to control their COP when voluntary postural limits of stability are stressed.

TARGET REACHING

Using Balance Trainer software v. 1.4.2 (Advanced Mechanical Technology, Inc.), circular targets were programmed to appear one at a time in a random order at eight positions set to a distance equal to 75% of the participant's total voluntary anteroposterior and medialateral voluntary limits of stability that were obtained prior to target reaching testing: (target #1), 65 (target #2), 90 (target #3), 135 (target #4), 180 (target #5), 225 (target #6), 270 (target #7), or 315 (target #8) degrees from a central position (target #0) (see Figure 1). The diameter of each target was set to 3% of the total lean diameter. Again, with their feet together, barefoot, while standing on a force platform, participants were asked to voluntarily shift their COP. Continuous real-time feedback of COP position relative to the targets was provided by a computer monitor placed directly in front of them. Participants were asked to shift their weight towards each target as quickly and accurately as possible when it would light up. Once the COP projection on the monitor fell within the target area, they were then required to hold it within the target perimeter for a total of three seconds before the next target would appear. Each trial lasted 60 seconds. Practice trials were provided to ensure full comprehension of the activity for all participants. Three trials were performed on both surface conditions (S and F) for a total of six trials. Since providing visual feedback of COP projection was a component of this accuracy task, no EC conditions were performed. Two dynamic variables provided by the Balance Trainer software were extracted for further analysis: (1) average COP wandering (cm); the accumulated length of the COP trajectory deviations from the straight line distance to the central point of the next target, and (2) average target overshoot (cm); the maximum straight line distance of COP movement beyond the outside of the perimeter of the target attempting to be attained.

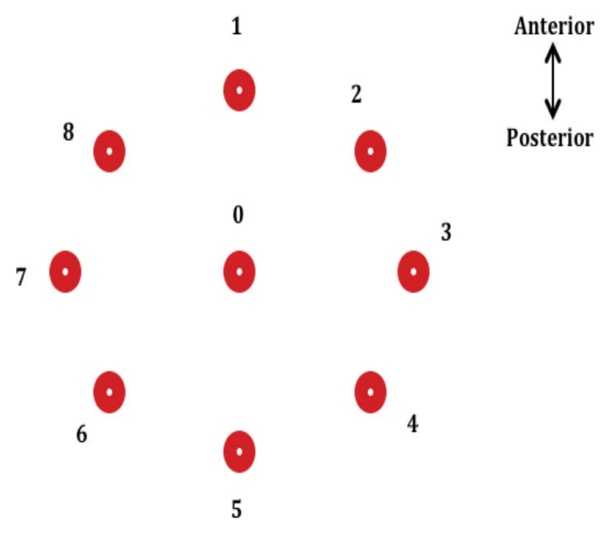

FIGURE 1. Target positioning relative to feet (i.e., voluntary limits of stability) for target reaching testing.

DATA ANALYSIS

Group averages and standard deviations of baseline performance measures were first calculated in order to describe absolute postural performance parameters under normal EO-S sensory conditions for each of the three tasks. Next, in order to reveal the extent to which each condition increased or decreased postural stability in each group (regardless of absolute performance), relative increase or decrease in COP variables was also calculated for each of the experimental sensory conditions (EC-S, EO-F, and EC-F) and expressed as a percent change with respect to the baseline trials ([[Condition X – EO-S]/EO-S] × 100). A relative measure of change in balance performance is especially important as anthropometric differences between individuals such as body mass and height have been shown to influence absolute values of postural sway variables (Handrigan, G. A., Berrigan, F., Hue, O., Simoneau, M., Corbeil, P., Tremblay, A., & Teasdale, N. et al., 2012; Kejonen, Kauranen, & Vanharanta, 2003). T-tests were used for between-group comparisons of baseline EO-S values for each postural task. For relative change measures of quiet standing and limits of stability tasks, a mixed-model analysis of variance (ANOVA) with one between-group (training status) and one repeated-measure (experimental sensory condition) factor was used in order to determine the main effects and interactions of training status and alterations in visual and/or somatosensory sensory conditions on postural stability. Additionally, a repeated-measures (target) ANOVA with one between-group (training status) was performed for relative change measures. Where appropriate, Tukey HSD was used for post hoc comparisons. All statistical analyses were conducted using SPSS (Version 20.0.0). The alpha level was set *a priori* at $\alpha = 0.05$.

RESULTS

BASELINE EO-S MEASURES

Baseline group comparisons showed that the untrained group had significantly greater anteroposterior dynamics ranges when normalized with respect to foot length ($p = 0.023$), while no significant differences were found for limits of stability sway velocities ($p = 0.307$) or either of the two quiet standing measures (sway area; $p = 0.408$, velocity; $p = 0.376$). For target reaching, untrained participants had greater target overshoots compared to strength-trained ($p = 0.040$), while a trend towards greater COP wandering in the untrained group was also observed; however this was not statistically different ($p = 0.074$) (Table 2).

QUIET STANDING PERFORMANCE

Statistical testing showed a significant condition effect for sway area and velocity ($p < 0.001$ and $p < 0.001$, respectively); however, no between-group differences for sway area ($p = 0.096$), or velocity ($p = 0.412$) were found. Therefore, both strength-trained and untrained participants had similar increases in sway area (EC-S vs. EO-F; $p = 0.022$, EC-S vs. EC-F; $p < 0.001$, EO-F vs. EC-F; $p < 0.001$) and velocity (EC-S vs. EO-F; $p = 0.008$, EC-S vs. EC-F; $p < 0.001$, EO-F vs. EC-F; $p < 0.001$) as the sensory condition became more challenging: EC-S being the least challenging, and EC-F as the most challenging (see Figure 2A and B).

LIMITS OF STABILITY PERFORMANCE

A significant condition main effect was found for relative change measures of AP mean dynamic range ($p < 0.001$) and sway velocity at maximal lean position ($p < 0.001$). In contrast to quiet standing, limits of stability relative change measures showed a significant training group main effect for anteroposterior dynamic range ($p = 0.017$), but not sway velocities ($p = 0.082$). In comparison to untrained participants, the strength-trained group experienced less reduction in dynamic range for all sensory conditions relative to baseline values (Figure 3A). Moreover, a significant training group x condition interaction was present for dynamic range ($p = 0.003$), as well as sway velocity at maximal lean positions ($p = 0.025$). Relative increases in sway velocities at leaning positions were significantly higher only for EC-F versus EO-F conditions ($p = 0.018$) in strength-trained participants (EC-F vs. EC-S; $p = 0.204$,

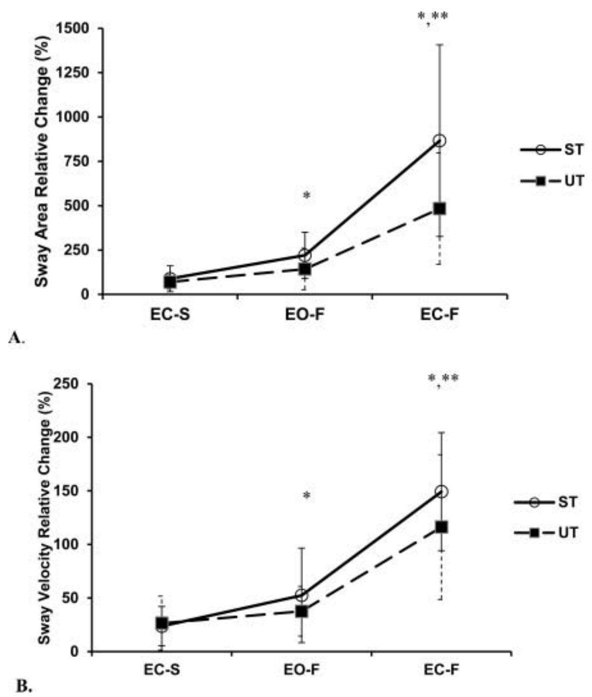

FIGURE 2. Relative (%) change in COP sway area (A) and velocity (B) for strength trained (ST) and untrained (UT) individuals during quiet standing with respect to EO-S conditions. Error bars denote SDs. * denotes significant difference from EC-S and ** denotes significant difference from EO-F for both ST and UT groups.

TABLE 2. Group mean (±SD) baselines values for eyes open-stable surface condition trials in strength trained and untrained participants; center of pressure (COP) sway area (cm^2) and velocity (cm/s), anteroposterior (A-P) dynamic range (%foot length), target overshoot (cm), and wandering (cm).

		Strength trained	Untrained
Quiet standing	**Sway area**	3.18 (2.61)	2.34 (1.25)
	Sway velocity	2.22 (0.44)	1.95 (0.66)
Limits of stability	**A-P range**	50.10 (6.01)*	56.74 (4.44)
	Sway velocity	2.87 (1.29)	3.39 (0.63)
Target reaching	**Overshoot**	0.61 (0.07)*	0.72 (0.10)
	Wandering	11.62 (0.88)	14.13 (0.93)

*denotes significant differences from untrained participants.

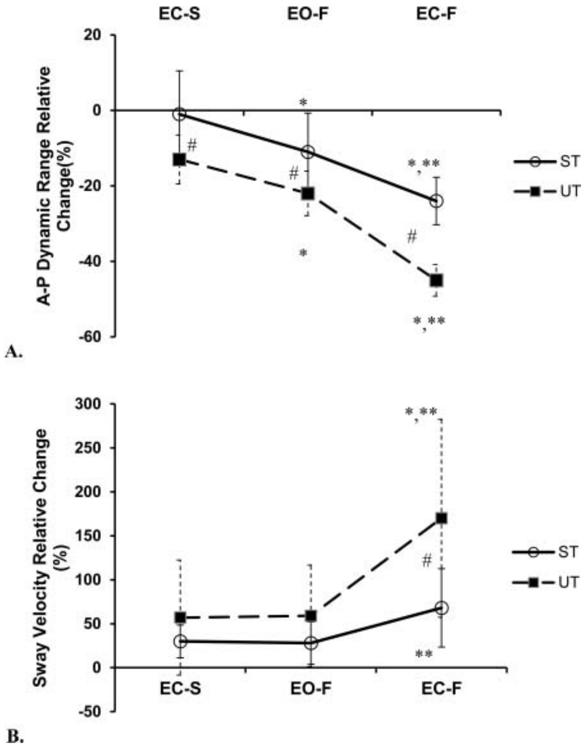

FIGURE 3. Relative (%) change in COP A-P dynamic range (A) and sway velocity (B) for strength trained (ST) and untrained (UT) individuals during limits of stability testing with respect to EO-S conditions. Error bars denote SDs. # indicates significant training group difference. * denotes significant difference from EC-S. ** indicated a significant difference from EO-F.

EC-S vs. EO-F; $p = 1.000$) and significantly higher between EC-F versus EC-S conditions ($p = 0.012$), and EC-F versus EO-F conditions ($p = 0.006$) (EC-S vs. EO-F; $p = 1.000$). Sway velocities of the strength-trained were only significantly different (lower than untrained) for EC-F condition ($p = 0.031$) (Figure 3B) during limits of stability testing.

TARGET REACHING PERFORMANCE

Relative changes in target COP overshoot and COP wandering from baseline to foam surface conditions showed no significant target effects ($p = 0.436$ and $p = 0.251$, respectively); therefore target data was combined and averaged for further analyses. No significant training group differences were found for COP overshooting ($p = 0.271$), while a trend towards significance was seen for between-group comparisons of COP wandering ($p = 0.086$) (Figure 4).

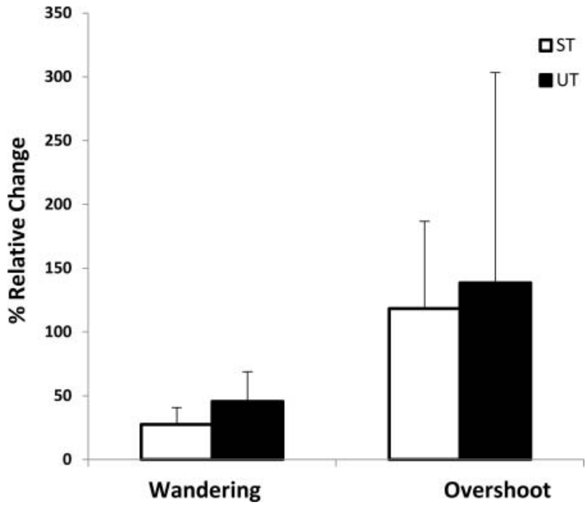

FIGURE 4. Change in relative performance of target reaching testing for strength trained (ST) and untrained (UT) participants between stable and unstable surface conditions.

DISCUSSION

The aim of this investigation was to determine the potential role of habitual strength training through the use of barbell free-weights in improving sensorimotor control of balance. COP sway variables were measured during both static and dynamic postural tasks of various challenging sensory conditions. The results of this investigation indicate that during dynamic limits of stability testing that involved stressing voluntary anteroposterior postural boundaries about the base of support, untrained participants experienced greater relative declines in postural stability. This was particularly noted when both vision was removed and surface compliance was altered. Although relative declines in quiet standing stability tended to be greater in the strength-trained group when sensory conditions were manipulated (Figure 2A and B), this was not found to be statistically significant; both untrained and strength-trained participants demonstrated statistically similar increases in postural sway areas and velocities.

In contrast, dynamic balance control in strength-trained participants was impaired less in all sensory conditions during the limits of stability maximal leaning task, notably in the EC-F sensory condition. Untrained participants experienced greater relative reductions in anteroposterior dynamic range when vision, surface compliance, or both were altered (Figure 3A). In turn, strength-trained and untrained groups showed similar relative increases in COP sway velocities at extreme postural limits when either vision was removed or somatosensory input was reduced; however group differences became apparent when both sources of input were affected simultaneously (Figure 3B). In combination with a restriction in voluntary postural limits of stability, greater increases in sway velocities while maintaining maximal lean positions would reflect an increase in the amount of postural corrections required to stabilize their body sway when balance is threatened (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998).

The use of a compliant memory foam surface reduces somatosensory information provided to the CNS by eliminating cutaneous mechanoreceptors' ability to accurately assess pressure distribution about the feet. This condition also causes conflicting feedback regarding ankle positioning relative to their COG and the support surface (Horak & Nashner, 1986; Kavounoudias, Roll, & Roll, 1998). Lastly, more processing time is required and the individual can become even more destabilized due to prolonged latencies in lower extremity muscle activity required to compensate for postural perturbations (Kejonen et al., 2003; Speers et al., 2002). Błaszczyk et al. (2009) suggested that reduced anteroposterior voluntary limits of stability were an indication of a more conservative postural strategy being adopted by excessively overweight individuals as a means to restrict COP deviations towards extreme postural limits about the feet. Interestingly, baseline comparisons between training groups of this current investigation showed that the strength-trained group had lower dynamic range absolute values (Table 2). Handrigan et al. (2012) found that greater body masses were associated with similar postural sway velocities in obese and heavy athletic individuals of similar body mass indexes, which was significantly greater than lighter controls. In contrast, stronger absolute and relative knee extensor strengths in the heavy athletic group had minimal effect on postural sway during normal quiet stance. This may explain the lower dynamic ranges of the strength-trained group who had greater body masses in this investigation (Table 1). Unfortunately, dynamic balance performance was not evaluated by Handrigan et al. (2012) and it is unclear if this body-mass dependent relationship would continue to exist during more challenging balance tasks. However, since the primary objective of this investigation was to determine the extent to which each group was impacted by altering sensory conditions, this possible confounding factor would be negligible once postural variables during the experimental conditions are normalized with respect to baseline EO-S values. When normalized, the removal of vision and/or somatosensory input from the feet impacted performance in the strength-trained group to a lesser extent than the untrained participants in this investigation. This finding supports our interpretation that a reduced anteroposterior dynamic range with increasing difficulty of the sensory condition would reflect that their balance was compromised to a greater extent compared to the strength-trained group when sensory constraints were altered. However, caution should be made when interpreting relative measures. For instance, since the strength-trained group had lower dynamic ranges during baseline limits of stability testing trials, their lower relative changes may be reflective of a more conservative control strategy already being adopted prior to sensory condition manipulations.

Reduced visual input to the CNS can impair motor output planning, and has been shown to compromise an individual's ability to quickly produce muscular force during dynamic tasks (Horvath, Ray, Croce, & Blanch, 2004; Killebrew, Petrella, Jung, & Hensarling, 2013); however, interestingly, Killebrew et al., (2013) showed that the ability to produce rapid and sufficient force in the absence of vision is preserved in strength-trained individuals. The authors suggest that resistance training may improve an individual's ability to sense body orientation when vision is removed in order produce accurate and rapid muscle contraction. This in turn has been shown to be essential in the control of posture (Maitre et al., 2015; Vuillerme & Pinsault, 2007). It is therefore possible that strength-trained participants in the current investigation did not require as great of a restriction in their anteroposterior voluntarily postural limits when sensory input was reduced, as they may have been able to more accurately sense and control their COP about their base of support. Although again, this may be due to lower baseline dynamic ranges of the strength-trained participants (i.e., it was already restricted), group differences in relative measures were more apparent as the difficulty of the sensory condition increased. During the most challenging EC-F sensory condition, neither group was able to increase the relative importance of visual feedback to sustain balance when stressing postural limits of stability on a compliant surface since the participants' eyes were closed. Therefore, our results may reflect a greater acuity and/or ability to extract additional somatosensory information from receptors during a challenging postural task (Vuillerme & Pinsault, 2007) in order to respond appropriately and rapidly to postural perturbations when vision is absent despite the altered surface compliance.

The target reaching accuracy task was used to compare multidirectional (anteroposterior and medialateral) dynamic balance control in strength-trained and untrained participants, when only somatosensory input was reduced as real-time visual feedback of their COP positioning about their base of support was provided on the computer monitor in front of them during testing. Baseline stable surface measures showed that strength-trained participants had significantly lower COP target overshooting, and a trend towards lower COP wandering compared to the untrained group was also observed (Table 2). This may suggest that strength-trained individuals have a greater COP control accuracy, and would reflect greater postural stability as rapid adjustments of COP path trajectories about the base of support are necessary in order to prevent one's self from falling, especially during dynamic movements (de Vries, E., Caljouw, S., Coppens, M., Postema, K., Verkerke, G., & Lamoth, C., 2014; Shumway-Cook & Woollacott, 1995). Moreover, an individual with greater overshooting of COP destinations would be at a greater risk of falling if their COP was to unexpectedly deviate outside of their postural limits of stability; therefore, lesser overshooting demonstrated by the strength-trained participants further supports that free-weight resistance training may improve their ability to sense rapid adjustments COP position about the base of support and in turn better regulate its movement during dynamic tasks. This does not suggest that the untrained individuals are at risk of falling, but rather there is a further improvement in postural task performance with habitual resistance training.

Lastly, relative changes in both COP overshooting and wandering for target-reaching testing were similar between groups when comparing stable versus unstable foam trials with their eyes open monitoring their COP positioning relative to the target on the computer monitor in front of them (Figure 4). A trend towards increased wandering was observed in the untrained participants; however this did not reach statistical significance. Therefore, although strength-trained participants had lower baseline overshooting values, it increased to the same extent as the untrained participants when asked to perform the task on a compliant foam surface. Since the task could not be performed without the use of visual feedback to hit the targets and only surface condition could be manipulated, these findings coincide with limits of stability performance measures during EO-F conditions. During postural conditions in which limits of stability are stressed and accurate control of COP about the base of support is required, training group differences are not apparent when only one sensory condition is manipulated. Therefore, these findings do not contradict the notion that training group differences are apparent when both vision and surface compliance are simultaneously impacted.

A limitation to this investigation is the small sample size of our two training groups, which can increase the probability of a type 11 error and finding no significant differences by chance. Although the current investigation is very novel, its findings provide evidence of sensorimotor-based adaptations associated with free-weight training that should be addressed by future research. Another limitation to this investigation is that group differences in strength were not accounted for. Unlike individuals with impaired balance due to neuromuscular declines, the untrained young adult participants in this investigation would have had sufficient strength to perform postural adjustments during both static and dynamic balance tasks (Pai & Patton, 1997; Winter, MacKinnon, Ruder, & Wieman, 1993). For example, Pai and Patton (1997) found that strength of the ankle musculature was only a significant limiting factor of postural limits of stability when the modeled dorsiflexion and plantar flexion strengths were reduced by 51% and 35%, respectively. Unlike body mass (Handrigan et al., 2012), strength was not expected to have been a prominent influencing factor responsible for the group differences observed when sensory conditions were manipulated.

Our results demonstrate that although postural stability in both the strength-trained and untrained groups was reduced to a similar extent during quiet standing testing, group differences became apparent as the task became increasingly dynamic. In particular, untrained participants required greater restrictions in their anteroposterior voluntary postural limits relative to baseline performance values, regardless of sensory manipulation conditions. Furthermore, when both sources of afferent input were challenged simultaneously (vision and surface compliance), the ability to remain stable appeared to be deterred less in the strength-trained group. Therefore, group differences observed in this investigation appear to be dependent on the nature of the task, and/or whether the condition was sufficiently challenging. A reduced ability to control COP near postural limits of stability may imply that in comparison to strength-trained participants, an individual from the untrained group would be less capable of accurately responding to and recovering from an unexpected perturbation when the sensory constraints of the environment are altered during dynamic tasks.

ACKNOWLEDGMENTS

We would like to thank Stephanie S. Bourbeau, Lisa Cormier, Sarah Trottier, Stephanie Battistin for their contribution in the data collection of this project.

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Received January 11, 2017
Revised November 27, 2017
Accepted December 13, 2017