5-2020

The effect of attentional focus instructions on single leg balance performance 2020.

Cory Monahan

The Effect of Attentional Focus Instructions on Single Leg Balance Performance

by

Cory Monahan

Submitted in Partial Fulfillment of the
Requirements for the Master of Science in Exercise Science Degree

Kinesiology Department

STATE UNIVERSITY OF NEW YORK COLLEGE AT CORTLAND

May 2020

Approved:

3 June 2020
Date

Wendy L. Hurley, Ph.D.
Thesis Advisor

3 June 2020
Date

Peter M. McGinnis, Ph.D.
Thesis Committee Member

3 June 2020
Date

Duane T. Graysay, Ph.D.
Thesis Committee Member

3 June 2020
Date

Eileen Gravani, Ph.D.
Associate Dean, School of Professional Studies

ABSTRACT

Balance and postural control exercises are often a part of exercise programs. During exercise programs, movement practitioners can provide instructions to facilitate performance and learning. Instructions can be used to direct attentional focus, which has been found to affect the performance and learning of motor skills, including balance and postural control tasks. However, no known studies to date have investigated the effect of both internal and external attentional focus instructions on static single leg balance performance. The purpose of this study was to investigate the effect of attentional focus instructions on static single leg balance performance as reflected by the complexity of the center of pressure (COP) profile. Data from forty-six participants between the ages of 19-28 years old were analyzed. Participants were divided into three groups: internal focus (INT) (n=15), external focus (EXT) (n=16) and control (CON) (n=15). Participants performed a thirty-five second static single leg balance task. Prior to the balance task, instructions were provided to participants which differed in the direction of attentional focus (internal or external focus), and the control group did not receive specific attentional focus instructions. Outcome measures were the scaling exponent determined from a detrended fluctuation analysis (DFA) to infer complexity of the COP profile in the anterior-posterior (AP) and medial-lateral (ML) directions, and root mean square error (RMSE) of the COP profile in AP and ML directions. A one-way analysis of variance (ANOVA) determined there were no statistically significant differences in the measured variables among groups. The results did not support the claim that manipulating the direction of attentional focus affects static single leg balance performance.

ACKNOWLEDGEMENTS

I would like to thank my mentor and role model Dr. Wendy L. Hurley. Thank you for your consistent willingness to guide my exploration as I pursuit my interests. You push me to improve and provide me with honest and constructive feedback. You have helped me to discover my passion. I am forever grateful for you! I am honored to have the privilege of learning from you and to call you my mentor.

I would like to thank Dr. Peter McGinnis for always having my best interest in mind and helping me to succeed. Thank you for always being available to discuss my questions and catering my educational experience to my goals. Your support and guidance has been instrumental in my development. Thank you for all that you do!

I would like to thank Dr. Duane Graysay for genuinely caring about my learning experience and for being one of the best educators I've ever worked with. You have helped me to expand my boundaries and develop a skillset that I am excited to continue to expand and build upon with you. Our discussions mean a lot to me. You've shaped the trajectory of my life in a very meaningful way. I feel fortunate to have established a relationship with you, and I am proud to look up to you.

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CHAPTER 1

INTRODUCTION

Among the many facets of physical fitness that are popularly trained in fitness programs are balance and postural control (Thompson, 2018; Thompson, 2019). Balance and postural control are related in so far as balance is a multidimensional concept referring to the ability of a person not to fall, and postural control is the act of maintaining, achieving or restoring a state of balance during any posture or activity (Pollock et al., 2000). When balance and postural control training is included in a multifaceted fitness program, it can provide injury-prevention benefits such as reduction in the occurrence of both ankle and knee injuries in athletes (Hrysomallis, 2007). Postural control training is prevalent in sport and therapeutic settings (Zech et al., 2010; Shubert, 2011) - environments in which movement practitioners can provide instructions to learners. An important aspect of instructions during motor skill performance and acquisition is the attentional focus that they facilitate (Nideffer, 1976; Nideffer, 1993; Wulf, 2013), namely external focus or internal focus (which will be discussed in a subsequent section). Nideffer (1976) originally classified attention as having two primary characteristics - width (broad/narrow) and direction (internal/external). The effects of the direction of attentional focus on motor performance and learning have been well studied using a variety of tasks (Wulf, 2013). Although the effects of attentional focus on balance and postural control have been investigated (Kim et al., 2017), few studies have investigated the effects of internal and external attentional focus instructions on static standing postural control tasks, defined as balance tasks during which the feet are fixed on a firm support surface (Vuillerme & Nafati, 2005; Polskaia et al., 2015); studies that have used static standing postural control tasks have often manipulated attention using secondary tasks (Donker et al., 2007; Cluff et al., 2010; Uiga et al., 2018) instead of using explicit attentional focus instructions. An investigation of the effects of providing internal and external attentional focus instructions on balance performance might guide decisions made by movement practitioners regarding providing attentional focus instructions to clients/patients performing static balance and postural control tasks. Dynamic systems theory offers a perspective from which such an investigation can be taken.

Dynamical systems theory provides a framework for the study of human movement science in which movement behavior is viewed as the result of self-organized pattern-forming processes (Kelso et al., 1987; Haken, 2010; Kelso, 1995) influenced by constraints arising from the organism, task and environment (Newell et al., 1989). Movement practitioners, when viewed from the dynamical systems perspective, act as change agents in an organism-task-environment system; they serve to manipulate the nature of the constraints acting on a client/patient in order to channel the dynamics of the movement system towards successful coordination solutions (Newell & Valvano, 1998). Therefore, from this perspective, it can be important for movement practitioners to consider the interaction of these constraints and their effect on movement behavior while designing and implementing programs and providing instructions/information to clients and/or patients. The constraints-led approach to skill acquisition entails strategically manipulating constraints to facilitate the emergence and discovery of functional movement solutions (Davids et al., 2008). Attentional focus instructions have been demonstrated as an important and effective constraint to manipulate during skill acquisition and performance (Wulf, 2013).

Two types of attentional focus that have been well-researched are external and internal attentional focus (Wulf, 2013). External focus is defined as consciously attending to details outside of the body, often regarding performance *outcome(s)*, whereas internal focus is defined as consciously attending to details within the body, often regarding the movement *process* (Nideffer, 1976; Wulf, 2013). Although the effects may be specific to the skill level of the performer (Castaneda & Gray, 2007), the task (Woo et al., 2014) and the nature of the internal focus (Kee et al., 2012; Komar et al., 2013), performance and learning are generally greater under external focus compared to internal focus conditions in a variety of tasks (Wulf, 2013). In studies using dynamic balance tasks (balance tasks in which the feet or surface is moving), results consistently show external focus instructions are superior to internal focus instructions (Kim et al., 2017). The effects of attentional focus on static standing postural control tasks (standing on a solid surface with feet stationary) have been studied by imposing secondary task demands (Cluff et al., 2010; Donker et al., 2007; Uiga et al., 2018), however, few studies have examined the effects of internal and external attentional focus instructions on static postural control and results tend to vary (Kim et al., 2017). Part of the inconsistency may be due to how stability of postural control is measured. Length, area and variability of center of pressure (COP) profiles have commonly been used to assess stability of posture, but Newell et al. (1993) suggest these measures alone are not sufficient; the attractor dynamics of the postural control system need to also be considered.

Assessments of the structure and correlation of fluctuations in center of pressure (COP) profiles during standing postural control are used to reflect the complexity of the behavior of the postural control system, and have been demonstrated as useful for determining the stability and functionality of postural control (Blaszczyk & Klonowski, 2001; Ghomaschchi et al., 2010; Ko & Newell, 2016). Complexity is a result of the non-linear interaction of many parts (degrees of freedom) on different spatial and/or time scales in a dynamic system and supports the ability to respond adaptively to internal and external demands; physiological systems exploit complexity for adaptable functionality (Lipsitz, 2002; Haken, 2010). Reductions in the complexity of COP dynamics are therefore typically interpreted as reflecting reduced functionality and ability to adapt to stressors. In fact, changes in complexity of COP dynamics have been associated with pathological postural control systems (Blaszczyk & Klonowski, 2001; Ghomaschchi et al., 2010), age-related declines in postural control (Ko & Newell, 2016; Uiga et al., 2018), and the risk of future falls (Zhou et al., 2017). Although lower complexity is typically associated with lower adaptability and pathology (Lipsitz, 2002), bi-directional changes in complexity which reflect a disruption in adaptive change in complexity might occur (Ko & Newell, 2016).

Few studies have investigated the effects of attentional focus on standing postural control using analyses of complexity. Differences in complexity have been found during postural control tasks under conditions of different attentional demands and strategies (Uiga et al., 2018; Kee et al., 2012; Donker et al., 2007), and complexity of COP dynamics has been associated with the degree of conscious involvement during postural control tasks (Uiga et al., 2018; Donker et al., 2007). However, to date there are no known studies that have investigated the effects of explicit internal and external attentional focus instructions on standing postural control performance as reflected by the complexity of COP profiles. Attentional focus has been manipulated by comparing single and secondary or suprapostural tasks (Uiga et al., 2018; Donker et al., 2007) and/or inferred using questionnaires (Uiga et al., 2018; Kee et al., 2012) instead of providing internal and external attentional focus instructions directly pertaining to the postural control task. An investigation of the effects of internal and external attentional focus instructions on postural control performance, as reflected by COP complexity, may have implications to coaches and therapists who provide instructions during balance and postural control exercises.

Research question

Does the direction of attentional focus affect static single leg balance performance?

Statement of problem

Although postural control often serves the purpose of supporting suprapostural tasks and is typically not performed for its own sake (Smart et al., 2004; Stroffregen et al., 1999), in exercise and therapeutic settings some postural control and balance training tasks are performed in and of themselves without suprapostural or secondary task goals (Zech et al., 2010; Shubert, 2011). Movement practitioners prescribing such balance tasks might wish to provide augmented information to performers with the goal of facilitating balance performance. Directing a performer's attentional focus is a strategy for improving performance that practitioners can use (Wulf, 2013). Investigations of the effects of providing attentional focus instructions during standing postural control tasks could have implications to movement practitioners prescribing and coaching balance and postural control exercises.

Purpose

The purpose of this study was to investigate whether the direction of attentional focus affects static single leg balance performance.

Hypotheses

H_0: The COP complexity will not be different between groups

H_a: The COP complexity will be different between internal and external focus groups

H_0: The amount of variability in the COP data will not be different between groups

H_a: The amount of variability in the COP data will be less in the internal focus group than the external focus group.

Delimitations

The delimitations of this study include:

1. Participants were 19-28 years of age
2. Participants did not wear glasses or have any self-reported visual impairments
3. Participants had no self-reported trouble with dizziness
4. Participants were not be experiencing pain or painful movement limitations
5. Participants had a BMI less than 30
6. Participants circled "No" in response to the following question: "To the best of your knowledge, do you have any physical condition(s) that may affect your balance and/or posture?"
7. Participants were not currently be participating in any other balance- or postural control-related research

Limitations

The limitations of this study include:

1. It is not possible to control for intentions; it can't be known with certainty whether the participants adopted the instructed attentional focus. Therefore, the results of this study capture the effects of attentional focus *instructions* on balance performance.
2. Standing on a force platform may not represent normal standing balance, as balance is typically not performed for its own sake, and task constraints can influence emergent

balance strategies (Smart et al., 2004; Stroffregen et al., 1999). Therefore, the results of this study should not be generalized to other balance tasks.

3. Task-specific, bi-directional changes in complexity have been found in older individuals compared to younger individuals (Ko & Newell, 2016). Postural control performance in children (9-18 years) has been shown to improve with increasing age (Paniccia et al., 2018). Participants in this study will be 19-28 years old, and therefore results should not be generalized to populations outside of this age range.

Assumptions

The following assumptions were made about this study:

1. Participants will follow the written instructions regarding where they should maintain their attentional focus
2. Participants will answer questions honestly

Definition of Terms

External focus	Paying attention to the effects of an action or something outside of the body during motor skill performance
Internal focus	Paying attention to the movement process, the body or proprioceptive information during motor skill performance
Postural control	The act of maintaining, achieving or restoring a state of balance during any posture or activity

Balance	The maintenance, achievement and/or restoration of the line of gravity within the base of support
Static postural control tasks	Exercises that challenge balance while the feet remain fixed on a stable surface
Dynamic postural control task	Exercises that challenge balance while the feet and/or support surface are in motion.
Suprapostural task	An action that a particular posture facilitates/supports
Secondary/dual task	A demand placed on a human during postural control that usually does not require extra movement, and requires the allocation of attentional and cognitive resources
Center of pressure	The point location of the vertical ground reaction force vector which represents the weighted average of all the pressures over the surface of the area in contact with the ground.
Center of mass	The point equivalent of the total body mass in the global reference system.

Significance of the study

This study could have implications to the provision of instructions from movement practitioners to learners during postural control and balance training protocols. During balance and postural control training programs, some practitioners utilize static balance and postural control tasks (Zech et al., 2010; Shubert, 2011). To date, no known studies have examined the effect of internal and external attentional focus instructions on static single leg postural control performance using complexity of COP as a dependent variable, which is reflective of functional and adaptable performance. This study will contribute to the existing body of research on the effects of attentional focus on balance and postural control, and potentially help practitioners choose appropriate instructions for learners to augment performance during static standing balance training exercises.

CHAPTER 2

LITERATURE REVIEW

Balance and postural control: Basic biomechanics and terms

Balance as defined by Pollock et al. (2000) is a multidimensional concept referring to the ability of a person not to fall, and postural control as the act of maintaining, achieving or restoring a state of balance during any posture or activity. Winter (1995) defined posture as describing the orientation of any body segment relative to the gravitational vector and defined balance as a generic term describing the dynamics of body posture to prevent falling. Thus, postural control and balance are intimately related. Two variables often involved in the measurement and characterization of balance and postural control are the center of pressure (COP) and the center of mass (COM). COP is defined as the point location of the vertical ground reaction force vector representing the weighted average of all the pressures over the surface of the area in contact with the ground, and COM is a point equivalent of the total body mass in the global reference system; it is the weighted average of the COM of each body segment in three-dimensional space (Winter, 1995). In the context of postural control, Winter (1995) refers to the center of gravity (COG) as the vertical projection of the COM to the ground. The COG is the point on a motionless rigid body where, if supported at that point, will remain balanced - it is the point where the weight of the body is considered to act (Robertson et al., 2014). According to one model of quiet stance control called the inverted pendulum model described by Winter (1995), control of quiet stance occurs predominately through pivoting at the ankle joint - much like an inverted pendulum. The horizontal acceleration of the COM is said to be proportional to the difference between the COG and COP. This model, however, has been argued to be inadequate because human balance and postural control is a complex process involving the control of *multiple* mechanical degrees of freedom (Wang et al., 2014; Alexandrov et al., 1998; Morasso & Schieppati, 1999; Aramaki et al., 2001; Hsu et al., 2007; Pinter et al., 2008).

For example, Hsu et al. (2007) tracked motion of the ankle, knee, hip, lumbo-sacral junction, cervical spine and atlanto-occipital joint in the sagittal plane during quiet standing. Analyses of variance of the joint motions suggested that all of the joints measured contributed to minimizing movement of both the COM and the head. Furthermore, coherence between pairs of joints was low, suggesting that motion at one joint could not directly represent movement at another. These results supported a more complex relationship among the measured joint motions during standing postural control, in contrast to the inverted pendulum model. Moreover, Aramaki et al. (2001) found that the angular motions around the hip and ankle joints served the role of minimizing COM acceleration, not maintain a constant COM position. These results also contrast the inverted pendulum model.

To fully capture the dynamics underlying human postural control, complex models are needed. Dynamic systems theory has offered a framework to develop such models through identification of relevant behavioral variables and their evolution in time, i.e., their dynamics (Kelso, 1995). Balance and postural control research grounded in dynamic systems theory has led to more understanding about the control strategies employed during quiet and perturbed stance in the context of self-organized pattern formation, as discussed in the next section.

Characterization of human balance and postural control

Balance in a static system occurs when the sum of gravito-inertial forces acting on the body are compensated by equal and opposite reaction forces from the support surface (Oullier et al., 2006). Human standing postural control in earth's gravitational field, however, involves continuous small amplitude movements occurring in multiple body segments in order to maintain the vertical projection of the center of mass (COM) within the base of support (Winter, 1995). As mentioned, to capture the complexity of human postural control, multi-segment models are needed, and dynamic systems theory and ideas from synergetics have proven useful for conceptualizing and modelling human postural control.

Concepts from dynamical systems and synergetics have been applied to human movement sciences to characterize spontaneous pattern formation in the human motor system (Kelso, 1995). Some basic terms used in dynamical systems and synergetics include: order parameters/collective variables, control parameters, phase transitions, hysteresis, critical fluctuations, critical slowing down, and attractor states, and multistability. *Order parameters*, or collective variables, are those that characterize the state of a system on a given level of analysis; they reflect the organization of the components of the system. *Control parameters* are those that, when varied, lead the system through different patterns, or states, of behavior. Changes in these parameters may not initially lead to observable change in behavior until they cross a critical value and lead to an abrupt transition in the order parameter. This is known as a phase transition. Moreover, when the direction of change of the control parameter reverses after a transition occurs, the system does not always transition back at the same value, but may persist for a longer time until it transitions back to its previous state. This tendency to remain in the current state is referred to as *hysteresis*. When a system is near a critical point and poised to transition, fluctuations in the value of the order parameter increase. These fluctuations are known as *critical fluctuations*. The time it takes the system to "relax" back to its state from a perturbation increases when the system is closer to its critical point. This is referred to as *critical slowing down*. Evidence of multiple (meta)stable attractor states of the collective variable (multistablity), phase transitions, critical fluctuations and critical slowing down suggests self-organized pattern formation in open, nonequilibrium systems (Kelso et al., 1987; Haken, 2010). Studies have applied such concepts to the study of human movement, including postural control (discussed next), which have found evidence of self-organization in the motor system and yielded systems-based characterizations of the coordination and control of standing posture.

A frequent collective variable identified in human movement research is relative phase, which captures the dynamic relationship between components of a system whose behavior is typically oscillatory in nature (Kelso, 1995; Davids et al., 2006). Relative phase has been identified as a collective variable that characterizes the relationship between the ankles and hips during standing postural control, which is evidenced by the presence of multistability, phase transitions influenced by control parameters, critical fluctuations, hysteresis and critical slowing down. Bardy et al. (1999), Marin et al. (1999), and Oullier et al. (1999) identified two predominant modes of coordination between the ankles and hips during standing postural control with tracking a back and forth moving target with their heads. The modes identified were an in-phase coordination mode in which the relative phase between the ankles and hips was approximately 20°, and an anti-phase mode, in which the relative phase between the ankles and hips was approximately 180°. These findings contrasted the notion that movement occurs predominately in the ankle, as in the inverted pendulum model. Bardy et al. (1999), Marin et al. (1999) and Oullier et al. (1999) demonstrated that the coordination mode that emerged was a function of the interaction of task and organismic and environmental constraints. For example, in Bardy et al. (1999), the amplitude of the target motion that they were instructed to track was varied among four conditions, and each individual’s center of mass was modified by adding mass to their body in three different locations (normal, low and high). Only two modes of coordination were identified: the in-phase and anti-phase modes. There was a transition from in-phase to anti-phase as the target amplitude increased, but the amplitude at which the anti-phase pattern occurred was a function of center of mass location. As the center of mass was raised, the anti-phase pattern occurred with lower amplitudes of target motion. Marin et al. (1999) investigated the effects of support surface (standard, foam and rollers) and target amplitude on coordination mode. Oullier et al. (1999) investigated the effects of target motion frequency on coordination mode. These three studies suggested center of mass, support surface and target frequency act as control parameters on the coordination variable of relative phase between the ankles and hips.

Oullier et al. (2002) provided further support of the two predominant modes of coordination between the ankles and hips, and also found that intention to sway affects the stability of these coordination patterns. Participants stood in a room which oscillated in the anterior-posterior direction with an amplitude matching normal postural sway amplitude. Frequency of the oscillations was manipulated, and participants were instructed to either track the target on the wall in front of them by maintaining the distance between the target and their head, or to merely watch the target. Coordination modes transitioned from in-phase to anti-phase as oscillation frequency increased under both tracking and watching conditions. However, the intention to sway (tracking condition) affected the *stability* of these patterns. These results support findings from experiments on the effects of intention on bimanual finger coordination (Kelso, 1995).

Findings regarding the variability of coordination patterns were also found by Bardy et al. (1999) and Oullier et al. (1999), who noted that the variability of the order parameter (relative phase) was lower for extreme values of the control parameters than the intermediate range, suggesting the presence of critical fluctuations (Kelso et al., 1987). Bardy et al. (2002) specifically designed their experiments to test for the hallmarks of self-organized processes: multiple stable states, phase transitions, critical fluctuations, hysteresis and critical slowing down- during postural control Their experiments found evidence of all of these properties. Taken together, the accumulated evidence supports the characterization of human postural control as an emergent behavior of a self-organized nonlinear complex system. However, previous results are not enough to make the claim that relative phase between the ankles and hips are the *only collective variable* of postural control tasks; a higher order collective variable has been suggested (Wang et al., 2014).

Wang et al. (2014) found evidence suggesting that the coherence between the COM and the COP is the higher order collective variable that is stabilized during postural control with feet side by side, single leg quiet standing, and single leg standing with body rocking at the ankle joint in the sagittal plane. Similar to previous research, a transition from in-phase to anti-phase of the ankle-knee and ankle-hip coordination was found as a function of rocking frequency. No transition occurred in the COM-COP coherence, although the strength of coupling seemed to decrease as frequency of rocking increased. Although past research has found strong evidence of self-organization in ankle-hip coordination patterns and considered these patterns to be collective variables, Wang et al. (2014) emphasized these patterns exist at the muscular-articular level. These authors therefore suggested that joint motions and their phase relations are *component* and *synergetic* variables, respectively, serving the purpose of stabilizing a more macroscopic collective variable which characterizes postural control at the space level: the COM-COP coupling.

Assessment of postural control using COP

A common means of investigation in human balance research has been analysis of the stabilogram, or a time-series of center of pressure (COP) data collected while standing on a force platform. Attempts have been made to directly assess stability with the variability of certain center of pressure parameters, but such assessments fail to capture finer details such as the structure of fluctuations in the data; more information about stability and control of posture can be obtained by also considering the attractor dynamics (Newell et al., 1993). While COP data alone is not sufficient for complete characterization of the coordination process of human balance, applying nonlinear analysis tools to COP data can capture meaningful information (Blaszczyk & Klonowski, 2001; Ghomaschchi et al., 2010). Moreover, analyzing COP data may be convenient and clinically practical for assessment of postural control performance (Ghomaschchi et al., 2010). One analytical tool that has been applied to COP data in human postural control research is the detrended fluctuation analysis (DFA).

The work of Einstein (1905/1956) has contributed to the development of methods for analyzing stochastic processes and assessing the structure and correlation properties of fluctuations in signals. Mandelbrot and van Ness (1968) generalized Einstein's work for application to fractional Brownian motion processes. Using this generalized relation, the DFA was developed for analyzing the structure and correlation of fluctuations in measurements of such processes and successfully applied in a wide range of fields, including the biological sciences (Peng et al., 1995; Delignieres et al., 2003). In their methodology paper on nonlinear time-series, Delignieres et al. (2003) suggested it is appropriate to apply the DFA to COP data during standing postural control tasks. Numerous studies have since demonstrated the usefulness of applying DFA to COP time series taken during postural control tasks.

Using DFA, Delignieres et al. (2011) analyzed center of pressure trajectory dynamics and found a cross-over from persistent to anti-persistent correlations in the bi-logarithmic diffusion plots generated from the DFA function for the velocity, but not position, COP time series. This means that large (compared to the average) velocities tend to be followed by larger velocities on short time scales, whereas on longer time scales there is alternation of large and small velocities. Subsequently, these authors inferred a velocity-based control strategy during quiet stance, because no cross-over was found in the position COP time series. It is important to note that the authors did not argue that velocity of COP is directly controlled during upright stance, as the COP motion is an outcome reflective of underlying control processes. Rather, it was suggested that velocity information perceived through the visual and proprioceptive sensory systems is used in the control of postural stability. As noted in the previous section, to adequately characterize the coordination and control of posture, COP data is not in and of itself sufficient; the relative phase of the ankles and hips (Bardy et al., 1999; Marin et al., 1999; Oullier et al., 1999) and the coherence of COP and COM (Wang et al., 2014) appear to be better suited for such characterization. Nonetheless, COP data can be used to infer meaningful properties of standing postural control.

Assessments of the structure and correlation of fluctuations in COP profiles during standing postural control have been used to reflect the complexity of the behavior of the postural control system, and have been demonstrated as useful for determining the stability and functionality of postural control (Blaszczyk & Klonowski, 2001; Ghomaschchi et al., 2010; Ko & Newell, 2016). System complexity has been suggested to reflect the ability to adapt to perturbations and indicative of the involvement and coupling of system degrees of freedom (Goldberger et al., 2002; Lipsitz, 2002). Physiological systems exploit complexity for adaptable functionality (Lipsitz, 2002; Haken, 2010). Changes in the complexity of COP dynamics are therefore typically interpreted as reflecting changes in functionality and ability to adapt to stressors. Analyses of the complexity of center of pressure time series collected during balance tasks have discriminated between pathological and healthy individuals (Blaszczyk & Klonowski, 2001; Ghomaschchi et al., 2010) as well as older and younger individuals (Duarte & Sternad, 2008; Uiga et al., 2018), identified task-specific, bi-directional change in complexity between older and younger individuals (Ko & Newell, 2016), demonstrated the ability to predict future falls (Zhou et al., 2017), and exposed effects of attentional demands (Donker et al., 2007; Uiga et al., 2018).

Effects of attentional focus on balance and postural control

Nideffer (1976) originally classified attention as having two primary characteristics- width (broad/narrow) and direction (internal/external). The effects of the direction of attentional focus on motor performance and learning have been well studied using a variety of tasks (Wulf, 2013). External focus is defined as consciously attending to details outside of the body, often regarding the *outcome* of the performance, whereas internal focus is defined as consciously attending to details related to the body, often regarding the movement *process* (Wulf, 2013). Although the effects may be specific to the skill level of the performer (Castaneda & Gray, 2007), the task (Woo et al., 2014) and the nature of the internal focus (Komar et al., 2013; Kee et al., 2012), a consistent finding is that greater performance and learning occur under external focus instruction compared to internal focus instruction and no instruction conditions (Wulf, 2013).

The constrained-action hypothesis was proposed as a potential explanation of the effects of internal and external attentional focus on motor performance and learning (Wulf, McNevin &

Shea, 2001). This hypothesis suggests that an internal focus of attention may over-constrain and interfere with the self-organized processes that lead to the emergence of functional behavior. Some of the support for the constrained-action hypothesis has come from findings in studies using balance tasks. Wulf, McNevin and Shea (2001) provide an early example. The authors found higher-frequency adjustments during performance on the stabilometer when participants adopted an external focus compared to internal focus, which is interpreted as evidence of increased exploitation of perceptual-motor degrees of freedom from an over-constrained movement system. Furthermore, reaction times were tested during the balance task to reflect attentional demands and compare between conditions. Consistent with the constrained-action hypothesis, reaction times were faster in the external focus group. Subsequently, it was concluded that a higher degree of automaticity and less conscious interference occurred under external focus conditions. Similar evidence is found from analyses of the complexity in center of pressure (COP) data during standing postural control under conditions of different attentional focus (Uiga et al., 2018; Kee et al., 2012; Donker et al., 2007), with reduced complexity typically associated with higher conscious involvement during postural control tasks. As discussed previously, complexity is reflective of the number of involved degrees of freedom and the ability to respond adaptively to internal and external demands (Liptsitz, 2002). Therefore, such findings can be taken as evidence of the constrained-action hypothesis.

The effects of attentional focus have been studied using a variety of balance and postural control tasks. Many studies have found superior effects of external focus instructions compared to internal focus instructions, however some have found minimal to no effect of attentional focus (see Kim et al. (2017) for a meta-analysis). The explicit provision of attentional focus instructions as well as the dual-task paradigm have been used. Researchers have used tasks such as the stabilometer (Wulf et al., 1998; Shea & Wulf, 1999; Wulf, McNevin & Shea, 2001; Wulf, Shea & Park, 2001; Chiviacowsky et al., 2010; Huang et al., 2014), standing on unstable surfaces such as balance boards and rubber wobble disks (Diekfuss et al., 2018; Wulf, 2008; Wulf et al., 2008), standing on a stabilometer or wobble disk with the suprapostural task of holding a tube horizontal (Wulf et al., 2003; Wulf et al., 2004, respectively) bilateral standing postural control (Landers et al., 2005; Vuillerme & Nafati, 2005), single-leg standing postural control (Kee et al., 2012), and postural control tasks with the addition of dual-tasks tasks such as reaction tests (Remaud et al., 2013), tone counting (Uiga et al., 2018) and cognitive tasks (Donker et al., 2007), and suprapostural tasks such as pursuit-rotor tracking task (McNevin et al., 2013), and stick balancing (Cluff et al., 2010).

Research that has used balance tasks which are more dynamic in nature (the feet and/or support surface moves) such as the stabilometer, balance boards and wobble disks, generally demonstrate improved performance and learning under external focus conditions (Wulf et al., 1998, Exp. 2; Shea & Wulf, 1999; Wulf, McNevin & Shea, 2001; Wulf, Shea & Park, 2001; Chiviacowsky et al., 2010; Huang et al., 2014; Diekfuss et al., 2018; Wulf et al., 2008). However, skill level may mediate these effects (Wulf, 2008). The effects of attentional focus on static postural control tasks are often investigated using the dual-task paradigm, with results generally demonstrating improved performance with attention on a secondary task compared to attention on the postural control task itself. Few studies have investigated the effect of providing attentional focus instructions during static standing postural control tasks.

Vuillerme and Nafati (2005) investigated the effects of attentional focus on bilateral standing postural control with the provision of attentional focus instructions. Participants were either instructed to focus on body sway (internal focus) or given no instructions (control). No external focus condition was used. COP root mean square (RMS) was used to quantify postural control performance, and the difference between the vertically projected center of gravity (COG) and COP was used to reflect muscular stiffness of the lower limb. The root mean square of the COG-COP difference was greater under internal focus conditions compared to control conditions, while the RMS of the COP alone did not vary between groups. The authors interpreted these results to reflect greater muscular effort to maintain a similar level of postural performance. Interestingly, these results seem like they may be related to the findings by Wang et al. (2014) who identified the coherence between the COM and COP to be a relevant macroscopic collective variable during standing postural control, as discussed previously.

Another study that used explicit attentional focus instructions is Polskaia et al. (2015). In this experiment, the effects of a cognitive secondary task, internal focus instructions and external focus instructions were compared during bilateral static standing postural control. Differences in stability were determined by sway area, sway variability and mean velocity. According to these parameters, the secondary task outperformed internal and external focus conditions, which did not significantly differ from each other. However, assessment of postural stability using parameters such as COP sway area, mean velocity, and variability are not sufficient (Newell et al., 1993); these authors discuss the need for assessing the attractor dynamics of the postural control system in order to characterize stability of posture. More appropriate techniques of assessing postural control performance from COP data using tools from non-linear dynamics have been developed and applied in research investigating the effects of attentional focus postural control, as previously discussed.

Using such non-linear tools, Donker et al. (2007) assessed standing postural control performance under single task and cognitive dual-task conditions with eyes open and eyes closed for each condition. Standard deviation, sway path length, scaling exponent, dimensionality, largest Lyapunov exponent and sample entropy were calculated. The introduction of a cognitive dual task, which was presumed to decrease attentional focus from the balance process, resulted in increased sway path length, increased dimensionality and decreased scaling exponent. These results suggested there was increased complexity in the COP dynamics when attention was withdrawn from the balance process, which supports the constrained-action hypothesis.

Uiga et al. (2018) also performed a non-linear analysis on COP data obtained during bilateral standing balance with and without a dual-task. In the single task condition, participants were instructed to stand as still as possible, while in the dual-task condition, a computer randomly generated tones, and participants were instructed to count the number of high-pitched tones. It is assumed that the dual-task reduces attention from the balance process. While there were no changes in any of the complexity-based measures between conditions, participants that were assessed as having a higher tendency to internally focus (using the Movement Specific Reinvestment Scale) had significantly lower measures of complexity under the single-task condition. This finding also supports the constrained-action hypothesis, and reinforces the idea that the effect of attentional focus on balance performance is related to an individual's predispositions/preferences to internal focus.

A complementary study, Kee et al. (2012), also found the effects of attentional focus on balance performance to be dependent on the individual's focus predispositions. Participants that performed an activity designed to facilitate "mindfulness," which is described as nonjudgmental present moment awareness (Brown & Ryan, 2003), showed evidence of higher complexity in COP profiles during subsequent single leg balance *only if they had a predisposition for mindfulness*. Participants with low mindfulness predisposition did not perform significantly different after the mindfulness-facilitating activity. Interestingly, more external focus strategies, such as staring at a spot on the floor, were adopted by participants after the mindfulness-facilitating activity.

Studies using suprapostural tasks have demonstrated little or no effect of attentional focus on postural control when the attentional focus manipulations were directed towards the suprapostural task. For example, Cluff et al. (2010) measured COP during standing balance with and without the dual-task of balancing a stick on one finger. External and internal attentional focus instructions were given with respect to the stick balancing task, not the postural control task. The stabilogram diffusion analysis (SDA) method was used to assess changes in the structure of fluctuations, however this method for COP data is not without criticisms (Delignieres et al., 2003). While there was a negative effect of internal focus instructions on performance in the stick balancing task, no effects of attentional focus on COP trajectories were found. McNevin et al. (2013), using a rotor-pursuit tracking task as a suprapostural task, also found minimal effect of attentional focus instructions on postural performance with attentional focus manipulations directed to the tracking task.

It is important to interpret results of studies using suprapostural tasks in the context of specific task constraints imposed by the suprapostural task (Smart et al., 2004; Stroffregen et al., 1999). While complexity of COP dynamics has been associated with the degree of conscious involvement during postural control tasks (Donker et al., 2007; Uiga et al., 2018), no studies have examined the effects of the explicit provision of both internal and external attentional focus instructions during standing postural control. Attentional focus has been manipulated using secondary tasks (Donker et al., 2007; Uiga et al., 2018) and/or inferred using questionnaires (Uiga et al., 2018; Kee et al., 2012) instead of providing attentional instructions directly pertaining to the postural control task. Although balance is usually not performed for its own sake (Smart et al., 2004; Stroffregen et al., 1999), there are times where the task goal is balance in and of itself, and these situations often emerge in exercise and therapeutic settings (Shubert, 2011). Therefore, understanding the effects of attentional focus instructions on standing postural control has implications to training interventions.

CHAPTER 3

METHODS

Participants

Forty-nine volunteers participated in this study. All participants provided informed consent to participate, and all procedures were approved by the university institutional review board (Appendix A). Participants were randomly assigned to one of three groups - an internal focus group (INT), an external focus group (EXT), or a control group (CON). Flyers regarding the opportunity to participate and essential details of the study (appendix B) were distributed to students in classrooms by instructors, and the flyers were also hung on hallway walls in campus buildings. The flyers clearly stated the inclusion criteria that the volunteers needed to meet to be eligible for the study. Those who responded were sent, via email, a consent form to review (appendix C), a questionnaire (appendix D) to confirm that they met the inclusion criteria. Participants were asked about orthotic footwear because orthotic footwear has been shown to affect static standing postural control (Hamlyn et al., 2012; Bateni, 2013). No participants reported wearing orthotics. No specific details regarding medical history were collected. Volunteers were asked to respond via e-mail or phone whether or not they intended to participate in the study on the provided day and time, and the appointment day and time was confirmed if they met the inclusion criteria. The volunteers were asked to bring a valid form of ID to the testing session to confirm their age. Inclusion criteria for participants were as follows:

1. 19-28 years old, because Ko and Newell (2016) found that postural control performance as measured by complexity of center of pressure (COP) dynamics is significantly different between young adults (in their study, 19-28 years old) and older individuals.

2. no self-reported trouble with vision and no eyeglasses, because visual impairments have been found to affect standing postural control performance (Schwesig et al., 2011).
3. no self-reported trouble with dizziness, because dizziness affects balance performance and the task employed in this study involves a challenging single leg balance task with only one trial permitted per participant; it is therefore important to optimize the chances of a successful trial on the first attempt.
4. no self-reported pain and/or painful movement limitations, because postural control has been found to be affected by painful movement limitations such as low back pain (Ruhe et al., 2011), experimentally-induced knee pain (Hirata et al., 2012), cervico-brachial pain (Karlberg et al., 1995) and in general nociception affects the ability of muscles to perform synergistic functions related to maintaining joint stability and control (Sterling et al., 2001).
5. a body mass index (BMI) score less than 30, because Blaszczyk et al. (2009) found differences in postural control performance in obese individuals classified as such by a BMI score of 30 or higher.
6. participants needed to circle “No” in response to the following question: “To the best of your knowledge, do you have any physical condition(s) that may affect your balance and/or posture?”
7. participants could not have been participating in any other balance- or postural control-related research to avoid influence of other instructions/information on their performance.

Height and weight (used for calculation of BMI) were reported by the participant. BMI categories were determined according to guidelines from the American College of Sports Medicine (American College of Sports Medicine & Kaminsky, 2006).

Design and procedures

Participants were scheduled for a single test date and time in the evening, and were asked not to participate in any exercise that day. Test sessions were scheduled in twenty-minute windows between September 26th, 2019 and February 27th, 2020. On each day of testing, at the beginning of the first test session and at the end of each subsequent test session, the force platform was sanitized using Wegmans Multi-Surface Disinfecting Wipes (Wegmans, 2020) according to the instructions listed on the product.

Participants were informed about the test procedure and specific details about the task they were to complete via written directions and a picture example of the posture they were asked to assume (Appendix E). Participants read the instructions while sitting at a desk. They were asked to balance barefoot on their *non-preferred* leg for one trial of thirty-five seconds duration on a force platform. The preferred limb was determined by asking the participant "if you would kick a ball at a target, which leg would you use to kick the ball?" The leg that would be used to kick the ball was considered the preferred leg. The participants were asked to stand on the leg that they would *not* use to kick the ball. This choice was made because Promsri et al. (2018) found that single leg postural control performance significantly differed between preferred and non-preferred limbs, with the distinction most pronounced when leg preference was determined for *dynamic tasks.* Promsri et al. (2018) therefore suggested that practitioners should consider the preferred dynamic leg during single leg standing postural control assessments. To determine dynamic leg preference, van Melick et al. (2017) determined that asking healthy adults “if you would [kick] a ball at a target, which leg would you use to [kick] the ball?” is reliable, and therefore is the question that was used in the present study.

Participants were instructed via written instructions (Appendix E) to stand on a visible line on the force plate which was parallel to the y-axis (A-P direction) of the force plate coordinate system. Participants were asked to stand barefoot to eliminate the influence of footwear on postural control in consideration of previous findings that have found different insoles to affect postural control (Christovao et al., 2013). As shown in the picture in Appendix E, a piece of yellow tape with a black line drawn centered along the length of the tape was placed along the center of the force plate in the anterior-posterior (A-P) direction. The position of the foot was such that the anterior-posterior line on the force plate, as shown in the picture in Appendix E, bisected the calcaneus and passed under the base of the second metatarsal, as described by Promisri et al. (2018). Arms were loosely crossed over the chest, and the non-support foot was placed behind the knee of the support leg, as in Kee et al. (2012).

Written instructions (Appendix E) were provided to the participants regarding the balance task. All instructions were identical among groups with the exception of the attentional focus instructions (see Appendix E). The INT group was instructed to “stand as still as you can, pay attention to your heart beat and try to count the number of times your heart beats during the balance task.” For the EXT group, a video of a cartoon (Maltese, 1994) was played during the balance trial and the participants were instructed to “stand as still as you can, watch the cartoon and count the number of times the cartoon switches scenes.” The CON group was instructed to “stand as still as you can.”

The flat screen television (SANYO Manufacturing Corp., DP26640) on which the cartoon was displayed was placed on a television cart that was fifty-four inches in height as measured from the floor to the top of the surface of the cart. The length of the base of the cart (the side of the cart facing the participant on the force plate) was thirty-two inches, and the width of the base of the cart was twenty-seven inches. The television screen had the following dimensions: width = 22.75 inches, height = 12.75 inches. Centering of the television on the surface of the television cart was visually approximated. The base of the television, after being initially placed on the surface of the television cart, was traced with a marker on the surface of the cart and not moved again for the duration of the study. The vertical distance from the ground to the center of the video monitor was 64.625 inches. The center of the force plate was 50.25 inches to the left of the wall of the laboratory (the wall was to the right side of the participant during the balance task) and the television was placed such that the center of the television screen was also 50.25 inches to the left of the wall. The distance from the front of the force plate (that participants stood on) to the center of the base of the television cart was eight feet. The length of the force plate that participants stood on was 23.375 inches, and the width was 15.75 inches. The television set-up as described above was present for all three conditions, but the television was turned off during the INT and CON conditions. The position of the wheels of the television cart were marked on the ground with two pieces of tape to ensure that the cart was positioned consistently for each testing session. The wheels were placed directly on the tape with the wheels of the cart oriented in the lateral direcetion (with respect to the force plate). The biomechanics laboratory where testing took place includes a black curtain eleven feet in height and hung thirty inches away from the wall (on the right of the participants) hung along the wall starting from the force plate and extending past the television cart.

The first ten seconds of data was not used in data analysis, as Kee et al. (2012) noted that due to the challenging nature of this task, large initial amplitudes of body movement tend to occur in this initial ten-second period as participants attempt to establish balance. Therefore, the final twenty-five seconds of data were considered the most suitable for assessing the sustained efforts in postural control. The participants were standing on the force platform facing away from the experimenter. Participants who broke form were omitted from the analysis. Breaking form was defined as either uncrossing the arms from the chest, or losing contact between the foot and the back of the knee. This was visually determined by the experimenter. Data were not used if participants lost their balance at any point during the trial, or if instructions were not followed properly regarding the form that participants were asked to use.

Instruments

Forces and moments (F_x, F_y, F_z and M_x, M_y M_z, respectively) were recorded by a force plate (Bertec Corporation, K00606 Type 4060-10), which was calibrated on September 26th, 2019 before collection of data began. The sampling frequency was 100Hz, because findings from Giovanini et al. (2017), who conducted analyses of the structure of fluctuations in COP time series, suggest a sampling frequency of 100Hz to record COP trajectories. Ruhe et al. (2010) also recommended a sampling frequency of 100Hz for COP data collection for analyses of postural control. A time series of the center of pressure (COP) in the anterior-posterior (A-P) and medial-lateral (M-L) directions was derived using built-in software (Contemplas professional motion analysis software, TEMPLO 2016.1.404).

Data processing and analysis

The following calculations were carried out using Matlab software (MathWorks, Inc., 2018b). The initial ten seconds of the data was not used in the data analysis to allow for initial adjustments to the balance task, as in the study by Kee et al. (2012), who utilized the same balance task as the one used in this study. Therefore, twenty-five seconds of COP data was used for analysis.

Giovanini et al. (2017) determined that for fractal analyses on COP trajectory data, filtering is advisable. With COP data recorded at 100Hz, detrended fluctuation analysis (DFA) was only able to distinguish postural stability between healthy individuals and stroke victims when the data was filtered. It was concluded that detrended fluctuation analysis would perform well with filtered data. Therefore, the M-L and A-P COP time series data were separately filtered with a dual pass, 2^{nd} order, 10 Hz low pass Butterworth filter as used by Giovanni et al. (2017).

The amount of variability was determined from the root mean square error (RMSE), calculated for the M-L and A-P directions, as follows:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

and

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \bar{y})^2}$$

Where N is the number of data points, x_i is i^{th} data point in the M-L component of the COP time series, y_i is the i^{th} data point in the A-P component, and $\bar{x}, \bar{y}$ are the means of the M-L and A-P COP series, respectively.

Complexity of the COP dynamics in both the M-L and A-P directions was assessed using detrended fluctuation analysis (DFA). DFA determines the fractal dimension of a time series and is relatively robust to non-stationarities in the time series (see Peng et. al., 1995 for details). The scaling exponent, α, calculated from the DFA reveals the correlation properties of the signal across different time scales, which reflects the complexity of the time series.

The process is as follows:

First, the N-point time series $\{z_t, t=1, . . ., N\}$ is centered at zero mean and cumulatively summed to obtain the integrated time series, as follows:

$$Z(t) = \sum_{u=1}^{t} (z_u - \langle z \rangle)$$

where

$$\langle z \rangle = \frac{1}{N} \sum_{t=1}^{N} z_t$$

is the global mean.

This series is then divided into a number of non-overlapping windows with an equal number, *w,* of data points. Hence, there are N/w windows. The size of the windows will range from 10 data points to N/4 data points, as suggested by Peng et al. (1994).

Within each window, the series Z(t) is detrended by a linear least square fit, $\hat{z}(t)$. Then the detrended fluctuation parameter, F(*w*), is computed as

$$F(w) = \sqrt{\frac{1}{N}\sum_{t=1}^{N}[Z(t) - \hat{z}(t)]^2}$$

where $\hat{z}(t)$ is a piecewise continuous function composed of the local least-square fit lines in each window.

Because F(w) obeys a power-law function such that $F(w) \propto w^{a}$, the scaling exponent α is obtained from the slope of the linear regression of a log-log plot of F(w) over w.

When α=1.0, the series is considered 1/*f* noise (pink noise) where *f* is frequency (the spectral power of the signal is inversely proportional to the frequency) and is maximally complex, while white noise (α=0.5) and Brownian noise (α=1.5) have lower or no complexity (Duarte & Sternad, 2008; Lipsitz, 2002; Peng et al., 1995). Moreover, α can be interpreted as the "roughness" of the series, with larger α reflecting "smoother" series than lower α (Peng et al., 1995).

The range of window sizes on which the slope of the log-log plot is evaluated was determined according to the process developed by the Center for Research in Human Movement Variability at the University of Nebraska at Omaha and used in Taylor (2015). In short, a range of window sizes was determined appropriate if it performs "reasonably well" when used in a DFA analysis of one hundred samples of pink noise (with a known alpha value of 1) with the same number of data points as the collected COP data. "Reasonably well" is defined as meeting the following requirement: the ninety-five percent confidence interval of the mean alpha value calculated from the one-hundred random trials must contain the known alpha value of 1 for pink noise. In other words, if a chosen window size did not perform reasonably well on a set of data with a known alpha value, it was not determined as suitable for the analysis of the collected data.

Delignieres et al. (2011) found that the log-log plot of COP position data did not show signs of the "cross-over" phenomenon, whereas COP velocity data did. The data collected in this study was COP position data, and therefore the range of window sizes was chosen on the basis of location on the log-log plot, but based on the results of the statistical test described above.

Statistical analysis

The statistical analysis was performed with SPSS software. The mean values of the root-mean-square-error (RMSE) and the scaling exponents calculated from the detrended fluctuation analysis (DFA) were each compared among groups (INT, EXT and CON) using a one-way analysis of variance (ANOVA). Data were inspected for normality and outliers. Q-Q plots were used to inspect the data for deviations from normality. Outliers were defined as data three or more standard deviations away from the mean, and if present were omitted from analysis. Levene's test of equality of error variances was used to determine if the assumption of homogeneity of variance was violated. Post-hoc tests with a Bonferroni correction were used to determine significant differences. Significance level was set to 0.05. The null hypotheses was rejected if the test statistic p-value was less than 0.05.

CHAPTER 4

RESULTS

Participants

Of the seventeen participants in the external focus group (EXT), one participant did not follow the instructions properly (did not cross arms over chest) and therefore the data for this participant were not included in the analysis. Sixteen total participants' data were included in the analysis for the EXT group. Of the sixteen participants in the internal focus group (INT), one participant did not successfully maintain balance for the entire duration of the trial and therefore the data for this participant were not included in the analysis. Fifteen total participants' data were included in the data analysis for the INT group. Of the sixteen participants in the control group (CON), one participant did not follow the instructions properly (did not place foot behind knee) and therefore their data were not included in the analysis. Fifteen total participants' data were included in the data analysis for the CON group. Descriptive statistics of participants are presented in Table 1.

Table 1

Participant descriptive statistics

Group	N	Age (years)		Gender		Height (inches)		Weight (pounds)		Leg balanced on	
		Mean	SD	Male	Female	Mean	SD	Mean	SD	Left	Right
External	16	20	1.2	8	8	68	3.6	161	18.1	12	4
Internal	15	21	2.4	7	8	67	4.7	165	31.4	14	1
Control	15	20	1.3	5	10	67	3.3	164	28.5	14	1

Note. N=number, SD=standard deviation

ANOVA

No statistically significant differences were found among groups for any of the dependent measures. The mean values and 95% confidence intervals for all measures and groups are provided in Table 2.

Table 2
Descriptive statistics

Dependent measure	External focus Mean 95% CI	Internal focus Mean 95% CI	Control Mean 95% CI
Scaling exponent M-L	1.1521 [1.0894,1.2147]	1.1726 [1.1078,1.2373]	1.1381 [1.0733, 1.2028]
Scaling exponent A-P	1.3149 [1.2314,1.3984]	1.3556 [1.2694,1.4419]	1.3411 [1.2549,1.4274]
RMSE M-L	0.0058 [0.0053,0.0062]	0.0053 [0.0048,0.0058]	0.0050 [0.0045,0.0055]
RMSE A-P	0.0069 [0.0059,0.0079]	0.0083 [0.0073,0.0093]	0.0070 [0.0060,0.0081]

Note. CI=confidence interval

Scaling exponent

For the scaling exponent of the medial-lateral direction (M-L) component of the center of pressure (COP) time series data, Levene’s test of equality of error variances was insignificant ($F(2,43) = 0.359$, $p = 0.7$). The one-way ANOVA did not yield significant differences among groups ($F(2,43) = 0.292$, $p=.748$). For the scaling exponent of the anterior-posterior direction (A-P) component of the COP time series data, Levene’s test of equality of error variances was insignificant ($F(2,43) = 2.289$, $p = 0.114$). The one-way ANOVA did not yield significant differences among groups ($F(2,43) = 0.242$, $p=.786$).

RMSE

For the root-mean-square-error (RMSE) of the M-L component of the COP time series data, Levene's test of equality of error variances was insignificant (F(2,43) = 1.601, p = 0.214). The one-way ANOVA did not yield significant differences among groups (F(2,43) = 2.110, p=.134). For the RMSE of the A-P component of the COP time series data, Levene's test of equality of error variances was insignificant (F(2,43) = 1.094, p = 0.344). The one-way ANOVA did not yield significant differences among groups (F(2,43) = 2.296, p=.113).

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Discussion

The purpose of this study was to investigate the following research question: does the direction of attentional focus affect static single leg balance performance? There were no statistically significant differences among groups for any of the measured variables, contrary to the hypothesis that the external focus group would yield better performance than the internal focus group. The results of this study do not support the claim that the direction of attentional focus affects static single leg balance performance characterized by the complexity of the center of pressure (COP) and the root-mean-square-error (RMSE) of the COP. Furthermore, as indicated by the lack of statistically significant differences between the control group and the experimental groups, the results do not support that a silent counting task affects static single leg balance performance regardless of whether the task is associated with internal or external focus of attention. The following discussion of these results takes place in three parts. First, the results are discussed in terms of the direction of attentional focus. Next, the results are discussed in terms of the use of secondary tasks. Finally, the overall results are interpreted and discussed within the dynamical systems theoretical framework.

Direction of attentional focus and balance performance

Although internal focus conditions often lead to detriments in performance and learning compared with external focus conditions (Wulf, 2013), the results have been mixed in the context of static standing balance (see Table 3).

Table 3
Effect of attentional focus on static balance performance

Study	Attentional focus conditions	Result
Present study	Counting heart beats | Counting cartoon scenes	No significant difference
Donker et al. (2007)	Eyes closed: Cognitive secondary task | No secondary task	Better performance with secondary task
Cluff et al. (2010)	While stick balancing: Focus on finger movement | Focus on stick movement	No significant difference
Kee et al. (2012)	Mindfulness facilitation | Control	Better performance with mindfulness for those with predisposition to be mindful
Uiga et al. (2018)	Assessment of conscious investment in postural control	Lower performance with higher conscious investment
Vuillerme & Nafati (2005)	Consciously monitor postural corrections | Control	Lower performance while monitoring postural corrections

Some studies have noted detrimental effects of internal focus (Uiga et al., 2018; Vuillerme & Nafati, 2005), one study found a beneficial effect of internal focus (Kee et al., 2012) and one study found no significant effect of internal focus (Cluff et al., 2010). Donker et al., 2007 increased conscious involvement in postural control by having participants close their eyes and either perform a cognitive secondary task (to decrease attention from postural control) or stand with eyes closed without a secondary task (assumed to have more attention on postural control. The found that performance was greater (higher complexity of COP time series) during the cognitive secondary task.

Although a detrimental effect of an internal focus of attention on static standing balance performance has been noted when the internal focus emphasizes consciously monitoring movement form (Uiga et al., 2018; Vuillerme & Nafati, 2005), Kee et al. (2012) found that a general state of "mindfulness" (***broad*** internal focus) can actually be beneficial for those that tend to be mindful, as reflected by the complexity of the COP time series during single leg standing balance. Therefore, it seems reasonable to claim that although focusing attention on corrections of postural sway is unlikely to be beneficial for static standing balance performance, in line with the constrained-action hypothesis (Wulf et al., 2001), a general awareness of sensations in the body may provide relevant information during standing balance and be beneficial for performance, as supported by the findings of Kee et al. (2012).

Based on the current literature, results are mixed as to whether the effects of attentional focus on static balance performance are related specifically to the *direction* of the attentional focus. The experimental conditions in the present study manipulated the direction of attentional focus without appreciably changing the demands of the task (both conditions involved a silent counting task) and no statistically significant differences were found. These results complement the study by Cluff et al. (2010) who measured balance performance while participants balanced a stick on one finger, and manipulated the direction of attentional focus internally and externally. No statistically significant differences were found between attentional focus conditions. Overall, these findings do not support that internally-directed attention is always inappropriate during standing single leg balance.

Secondary task conditions

When the instructions are to "stand as still as possible," the addition of a counting secondary task did not seem to lead to significant differences in performance regardless of the direction of the focus, as indicated by the lack of significant difference in any of the measured variables among CON, INT and EXT groups. There have been mixed findings in the literature on the effects of performing secondary tasks on static balance performance compared to single task conditions (see Table 4).

Table 4
secondary tasks on static balance performance

Study	Secondary task conditions	Result
Cluff et al. (2010)	Stick balancing | Control	Better performance stick balancing
Donker et al. (2007)	Speaking names backwards | Control	Better performance while speaking names backwards
Uiga et al. (2018)	Silent tone counting | Control	No significant difference
Cluff et al. (2010)	Silent arithmetic | Control	No significant difference
Present study	Silent heart beat counting | Silent cartoon scene counting | Control	No significant difference

In the study by Cluff et al. (2010), non-linear analyses on COP trajectories indicated that balance performance improved (increased complexity) with the addition of stick balancing as a secondary task compared to the single-task control condition. Donker et al. (2007) found statistically significant differences in the complexity of COP trajectories between single-task and secondary task conditions during bilateral standing balance. The secondary task used by Donker et al. (2007) was speaking names backwards that were spoken to them by the researcher. Uiga et al. (2018) found that silently counting tones as a secondary task during static standing balance did not yield statistically significant differences in the complexity of COP trajectories between single and secondary task conditions. Interestingly, Cluff et al. (2010) also used a silent arithmetic dual-task in their study (the participants did not *speak* their answer during the balance task), which did not yield differences in balance performance as reflected by the complexity of the COP time series. A possible explanation for the lack of significant effect of the secondary tasks on balance performance in the present study, tone counting in Uiga et al. (2018), and the silent arithmetic task in Cluff et al. (2010), compared to the effect of stick balancing in Cluff et al. (2010) and speaking names backwards in Donker et al. (2007), might be related to the nature of the secondary tasks. The secondary tasks in the present study, Uiga et al. (2018) and Cluff et al. (2010) (silent arithmetic) did not require motor responses, unlike stick balancing and speaking names backwards. Since posture is typically performed to support suprapostural tasks (Smart et al., 2004; Stroffregen et al., 1999), it is reasonable to suspect that the motor responses required during stick balancing and speech are related to the significant differences in COP complexity between groups in Cluff et al. (2010) and Donker et al. (2007). Cluff et al. (2010) noted changes in the timescale of postural corrections during the stick balancing in the form of a “drift and correct” mechanism; the postural dynamics reflected the task demands of stick balancing. Although the motor component of the secondary task used in Donker et al. (2007) only required speaking, it is worth noting that even uttering simple syllables such as “pa” uses as many as seventy muscles which control respiratory, velar, facial, pharyngeal, laryngeal, lingual and masticatory movements (Abbs & Connor, 1989). Lagier et al. (2010) provided evidence that vocal effort and posture do seem to be functionally coordinated together. As Lagier et al. (2010) note, vocal effort involves the whole body. Therefore, the speech component of the secondary task used in Donker et al. (2007) might be related to the increased complexity of the COP dynamics in the secondary task condition. In Cluff et al. (2010) and Donker et al. (2007), the focus on the secondary task might be considered as “relevant” with respect to the postural control task if the postural control system was functioning in a subservient way to the secondary task demands. In other words, the focus might be considered as directed to the *outcome* of the movement process if the postural control system acted as a component of the processes functioning to serve the motor performance of the secondary tasks. A consistent finding in attentional focus research is that when focus is on the *outcome* of the movement process (typically described as external focus) as opposed to the movement process itself (typically described as internal focus), performance and learning is superior (Wulf, 2013). In this light, research on the effects of secondary motor tasks on postural control performance are consistent with most of the research on the effects of attentional focus on motor performance.

Interpretation within dynamical systems framework

A possible explanation for the seemingly mixed results of the effect of internal and external attentional focus on static balance performance may be related to the nature, relevance and usefulness of the information attended to among the experimental conditions. Coordination, from the dynamical systems perspective, is viewed as a self-organized process, the dynamics of which are affected by the confluence of constraints arising from the individual, task and environment (Davids et al., 2003; Newell & McDonald, 1991); information delivered by all of the sensory systems constrain coordination dynamics through the process of self-organization (Newell & McDonald, 1994; Profeta & Turvey, 2018). According to dynamical systems theory and the ecological approach to perception and action, perception is viewed as a functional act of picking up information to use for regulating actions (Chow et al., 2016), and skillful performance is related to becoming attuned to relevant information that is used to constrain movement behavior to accomplish a particular goal (Kugler & Turvey, 1987; Fajen et al., 2008; Pacheco et al., 2019). Bernstein (1945-46/1996) characterized the role of allocating attentional resources, hypothesizing that the level to which attention is allocated leads in the control of movement, and that attention should be on the desire to solve the motor problem (Bernstein, 1945-46/1996); the relationship between what is attended to and the task goal is important. The information attended to will be located somewhere, and can be characterized as being located internally or externally (Nideffer, 1976). It is clear that postural dynamics are related to visual information (Lee & Lishman, 1975; Oullier et al., 2002; Smart et al., 2004; Stoffregen et al., 1999) which is located externally, and proprioceptive information (Peterka & Loughlin, 2003) which is located internally. Therefore, perhaps the effects of attentional focus instructions should be considered closely in terms of the *content* and *relevance* of the information attended to with respect to the constraints that define the context of the task being performed as opposed to specifically the direction of focus. In this light, the interplay between internal and external attentional focus during static standing postural control might become evident. For example, Kee et al. (2012) noted that for participants that had tendencies to be mindful, participating in a mindfulness facilitation task- in other words, facilitating a broad internal focus- resulted in improved performance as indicated by the complexity of the COP time series. Furthermore, these participants reported more use of external information compared to the control condition as indicated by responses to a questionnaire. Participants indicated utilizing “some spots” to look at while balancing, but responses in the questionnaire regarding using “a fixed spot” to look at was not significantly different between groups. This might have been indicative of a more “flexible” mode of perception allowing participants to adapt to ongoing demands as opposed to rigid fixation on narrow information (Kee et al., 2012). These results support the suggestion of Yi-Ching Peh et al. (2011), who discuss that narrow internal attentional focus instructions commonly used in research might be too rigid and over-constraining. The dynamics of perception are self-organized patterns themselves (Pacheco et al., 2019), and perception and action are circularly related to each other (Pacheco et al., 2019); each influences and supports the other. Variability in the dynamics of perception and action support skilled behavior (Seifert et al., 2013). It is in this light that Yi-Ching Peh et al. (2011) argue that the usefulness of internal focus might be underemphasized, and that both might play an important role in the development and performance of perceptual-motor skills. As the philosophical perspective of complementarity (Kelso & Engstrøm) would have it, perhaps internal and external focus are complementary. Future research investigating the interplay between internal and external focus during static standing postural control tasks might yield important insight about how attentional focus affects static standing postural control performance.

When information is considered as relevant, it is considered as such with respect to a particular task goal (Turvey & Kugler, 1984; Kugler & Turvey, 1987; Fajen et al., 2008; Pacheco et al., 2019). As Pacheco et al. (2019) suggest, attentional focus might act as a constraint that alters the coupling of perception and action, and attentional focus instructions can constrain the learner to perform *based on* the information their attention is channeled to. Therefore, as Yi-Ching Peh et al. (2011) suggest, the relationship between attentional focus instructions and the perceived goal of the task is important to consider. When relevant information with respect to the task goal is located internally, internal focus might be appropriate as supported by research on attentional focus instructions using tasks such as taekwondo routines (Woo et al., 2014) and swimming emphasizing movement form (Komar & Chow, 2013). If the nature of attentional focus instructions used in research conflict with the goal of the performance, the effectiveness and usefulness of both internal and external attentional focus might not be exposed (Yi-Ching Peh et al., 2011). In this light, to learn more about how internal and external attentional focus impacts static standing postural control, comparing how different attentional focus instructions qualitatively affect variables related the movement process might be useful.

It is worth noting that there is a subtle ambiguity in how the terms *internal attentional focus* and *external attentional focus* are used. Nideffer (1976) originally characterized attentional focus with a two-dimensional classification system: *width* and *direction.* According to Nideffer (1976), an internal focus of attention involves directing attention to one's own body, actions and/or thoughts, and an external focus involves directing attention to information arising from the environment, typically related to the performance of some task. In much of the research investigating the effects of the direction of attentional focus on the performance and learning of motor skills (see Wulf, 2013) an *external focus of attention* is defined as focusing on information pertaining to the *outcome* of an action, and an *internal* focus of attention is defined as focusing on the movement *process.* This definition is not always reflected in the instructions used in attentional focus research. For example, Wulf et al. (2007) investigated the effects of the direction of attentional focus on jump-and-reach performance where the external focus group was instructed to focus on reaching for the rungs of the apparatus, and the internal focus group was instructed to focus on their fingertips. Wulf et al. (2001) characterized internal focus during performance of the stabilometer test as focusing on one's feet, while an external focus was characterized as focusing on markers placed on the stabilometer platform. However, Wulf et al. (1998), during performance of a ski simulator, had participants either focus on putting force through the outsides of the feet (internal focus) or focusing on the force put into the wheels of the apparatus (external focus) which is more in line with the *process* and *outcome* definition of internal and external focus, respectively. Thus, clearly operationalizing these terms is important. As long as task performance outcome-related information is located externally, the characterizations of *external* and *internal* focus as described by Wulf (2013) and by Nideffer (1976) do not conflict very much, but when performance outcome related information is located internally (related to one's body), for example during taekwondo routines (Woo et al., 2014) and swimming emphasizing movement form (Komar & Chow, 2013), the consistent finding that an "internal" focus of attention (focusing on one's body) causes performance decrements does not seem to hold. In fact, in Komar and Chow (2013), the *outcome* being measured was movement form - in other words, the process was the outcome. In this case, differentiating *internal* and *external* focus as *process* and *outcome* focused attention, respectively, is not straight forward. A similar statement might be made about postural control tasks - the task "stand as still as you can," as was used in the present study, implies a relationship between the process and outcome in such a way that it is not easily distinguished.

In the present study it was decided to operationalize the definitions of the directions of attentional focus - *internal attentional focus* and *external attentional focus* - in line with Nideffer's (1976) characterization of the direction of attentional focus. Both experimental conditions in the present study involved attempted manipulations of the direction of the attentional focus (counting heart beats and counting cartoon scene changes) without appreciably changing the relevance of the focus (with respect to the balance task), and the results did not yield statistically significant differences among groups. The results therefore do not support that manipulating the direction of attentional focus alone is sufficient to affect static single leg balance performance, supporting the above discussion on the importance of considering the nature and relevance of the information attended to.

It is worth noting that, although the present study did not detect significant differences among groups, it cannot be ruled out that other outcome measures might have yielded differences. It is also important to note that the anterior-posterior positioning of the participants on the force platform was not prescribed, and the height of the video monitor was not matched for the height of each participant. Since these factors relate to the orientation of the participant with the monitor they were looking at, these confounding variables might have introduced error. Furthermore, the results of the present study should be interpreted within its limitations. Although written instructions were provided to participants intended to manipulate the direction of their attentional focus, it is not possible to control for the intentions of the participants. No follow-up questionnaires were used to assess the participants' adherence to the written instructions, nor were participants asked to report their count of total number of heart beats or cartoon scene changes. Therefore, one cannot state with confidence that these results reflect the effect of the direction of attentional focus, because attentional focus was not measured; these results reflect the effects of the particular written instructions provided to the participants to the extent that participants read, remembered and attempted to follow the written directions provided to them prior to the performance of the balance task.

Conclusions

The purpose of this study was to investigate whether the direction of attentional focus affects static single leg balance performance. Balance and postural control training is a popular part of physical fitness training (Thompson, 2018; Thompson, 2019), and it is common for physical fitness training be performed under the guidance of movement practitioners (Thompson, 2018; Thompson, 2019). According to the constraints-led approach to skill acquisition (Davids et al., 2008), manipulation of the attentional focus of a learner is a strategy that can be used by movement practitioners to facilitate performance and learning of motor skills. The results of the present study do not support the proposition that the direction of attentional focus alone is sufficient to improve static single leg balance performance as reflected by the scaling exponent and RMSE of the COP time series. Furthermore, the results do not suggest that utilizing a silent secondary counting task affects static single leg balance performance, regardless of the direction of attentional focus associated with the counting task. Based on these results, it is probably a good idea that practitioners should consider more than just the direction of the attentional focus of the performer if the goal is to facilitate balance performance. Future research might address whether instructions should be provided in the context of balance itself or whether balance is best to be practiced and instructed in the context of secondary or suprapostural tasks. Additionally, future research could address whether the effect of performing secondary tasks on static balance performance is different for secondary tasks requiring a motor response compared to secondary tasks that do not require a motor response. Overall, the results of this study suggest that when providing attentional focus instructions, it seems important to consider not only the direction of the focus of attention, but also the nature and content of the information attended to in relation to the task goal, and whether the provision of the internal and/or external attentional focus instructions changes task constraints.

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APPENDIX A: IRB Approval Letter

SUNY Cortland
Institutional Review Board

MEMORANDUM

To:	Cory Monahan Wendy Hurley
From:	Thomas Frank, Reviewer *on behalf of* Institutional Review Board
Date:	August 30, 2019
RE:	Institutional Review Board Approval

In accordance with SUNY Cortland's procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

Title of the study:	The effect of attentional focus instructions on single leg balance performance		
Level of review:	**Expedited**	**Protocol number:**	181940
Project start date:	Upon IRB approval	**Approval expiration date*:**	8/29/2020

* **Note:** *Please include the protocol expiration date to the bottom of your consent form and recruitment materials.* For more information about continuation policies and procedures, visit www.cortland.edu/irb/Applications/continuations.html

The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to irb@cortland.edu within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

Miller Building, Room 206 • P.O. Box 2000 • Cortland, NY 13045-0900
Phone: (607) 753-2511 • Fax: (607) 753-5995

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email irb@cortland.edu or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit http://www.cortland.edu/irb/members.html to obtain a current list of IRB members.

Sincerely,

Thomas Frank, Reviewer *on behalf of*
Institutional Review Board
SUNY Cortland

APPENDIX B: Recruitment Flyer

Are you interested in participating in a research study about balance?

Cory Monahan (SUNY Cortland masters student) is conducting a research study about the effects of attentional focus instructions on single leg balance performance.

The experiment consists of one (1) test session lasting approximately twenty (20) minutes. The test date and time will be provided to you by Cory. Test sessions will take place in the SUNY Cortland biomechanics laboratory.

Please note you will be asked to abstain from physical exercise on the day of testing.

To be eligible for participation, you must fit *all* of the following criteria:

- You must be 19-28 years old
- No trouble with vision, near or far, *and* no eyeglasses for vision correction
- No current trouble with dizziness
- No current pain or painful movement limitations such as pain in the ankle, knee, hips, low-back, neck, etc…
- A body mass index (BMI) score less than 30 (see chart below)- you must fall within the blue, green or yellow sections based on your height and weight.
- To the best of your knowledge, no current physical condition(s) that may affect your balance and/or posture
- You cannot be currently participating in any other balance- or postural control-related research

BMI Chart

Underweight | Healthy | Overweight | Obese | Extremely obese

WEIGHT lbs	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215
kgs	45.5	47.7	50.0	52.3	54.5	56.8	59.1	61.4	63.6	65.9	68.2	70.5	72.7	75.0	77.3	79.5	81.8	84.1	86.4	88.6	90.9	93.2	95.5	97.7
HEIGHT in/cm																								
5'0" - 152.4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
5'1" - 154.9	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36	37	38	39	40
5'2" - 157.4	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	33	34	35	36	37	38	39
5'3" - 160.0	17	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	32	32	33	34	35	36	37	38
5'4" - 162.5	17	18	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	31	32	33	34	35	36	37
5'5" - 165.1	16	17	18	19	20	20	21	22	23	24	25	25	26	27	28	29	30	30	31	32	33	34	35	35
5'6" - 167.6	16	17	17	18	19	20	21	21	22	23	24	25	25	26	27	28	29	29	30	31	32	33	34	34
5'7" - 170.1	15	16	17	18	18	19	20	21	22	22	23	24	25	25	26	27	28	29	29	30	31	32	33	33
5'8" - 172.7	15	16	16	17	18	19	19	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	32	32
5'9" - 175.2	14	15	16	17	17	18	19	20	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	31
5'10" - 177.8	14	15	15	16	17	18	18	19	20	20	21	22	23	23	24	25	25	26	27	28	28	29	30	30
5'11" - 180.3	14	14	15	16	16	17	18	18	19	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30
6'0" - 182.8	13	14	14	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29
6'1" - 185.4	13	13	14	15	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28
6'2" - 187.9	12	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27
6'3" - 190.5	12	13	13	14	15	15	16	16	17	18	18	19	20	20	21	21	22	23	23	24	25	25	26	26
6'4" - 193.0	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20	21	22	22	23	23	24	25	25	26

If you are interested in volunteering to participate in this research study, Contact Cory Monahan at cory.monahan@cortland.edu for complete details

APPENDIX C: Informed Consent Document

INFORMED CONSENT FORM

Title of study: **The effect of attentional focus instructions on single leg balance performance**

Principal Investigator: Cory Monahan

Participant's Printed Name: ____

You are invited to take part in a research study which seeks to identify how attentional focus instructions may affect single leg balance. This research is being conducted by Cory Monahan, a graduate student at SUNY Cortland. Your informed consent is requested if you wish to participate as a research subject in this study. Before you consent to participate, please read the following regarding the details of the study so that you fully understand what your involvement will be and what risks and benefits you may experience as a participant in this research. If you decide you would like to participate, you will be asked to sign a copy of this document when you report for your test session. You will not be permitted to participate in this study without having read and signed this document. **Taking part in this study is entirely voluntary. You are encouraged to ask any questions you may have regarding participation in the study.**

PURPOSE OF THE STUDY

This research study is being done to find out if attentional focus affects the performance of single leg balance. Results of this study may have implications to movement coaches and therapists.

ELIGIBILITY

You are eligible to participate in this study if you:

- are 19-28 years old
- have a body mass index (BMI) less than 30
- do not have any difficulties with vision nor do you wear glasses
- are not experiencing trouble with dizziness
- do not have any pain or painful movement limitations (for example, pain in the ankle, knee, hip, low-back, neck, or any other area of the body)
- do not have any physical conditions, that you are aware of, that may affect your balance and/or posture
- are not currently participating in any other balance- or postural control-related research.

PROCEDURES

On the day of testing, you will be asked to abstain from physical exercise. When you arrive for your scheduled appointment, you will be asked to sign this consent form. You will then be asked to read instructions that will explain the balance task. You will be asked to remove your shoes and socks, and if you are wearing long pants that extend past your ankles, you will be asked to roll them up just above your ankles. You will then be asked to stand and balance on one leg barefoot for thirty-five (35) seconds on a platform that measures forces. The instructions will specify a particular form required during the balance task, along with specific attentional focus instructions that you will be asked to adhere to.

The force platform will be sanitized prior to your participation for hygiene purposes.

DURATON OF YOUR INVOLVEMENT

If you agree to take part in this study, your scheduled test session will last approximately twenty minutes.

DISCOMFORTS AND RISK

Participating in this study involves a challenging balance task, which poses a risk of falling.

POTENTIAL BENEFITS

You will not directly benefit from taking part in this research study.

The results of this research may guide future movement practitioners in providing instructions to clients/patients during balance exercises. More information about the effects of attentional focus on human balance performance may be gained.

STATEMENT OF CONFIDENTIALITY

Your research records from this study will be kept by the principal investigator. All electronic data collected will be stored in a password-protected file on the principal investigator's personal computer as well as a password protected external hard drive,.Paper documents will be kept in a confidential folder and envelope. Your name will be associated with a numerical code so that the data collected during testing will not be directly associated with your name. Documents that will have your name directly attached are: 1) this consent form, 2) the questionnaire that you will complete during your appointment, 3) a schedule containing your one-time appointment, and 4) a list of codes assigned to each participant, which will include your name and e-mail address.

The documents and data will be transported by the investigator to and from the the SUNY Cortland campus and the investigator's home. After the research study has ended, your information will be stored in the investigator's home for a minimum of three years (in accordance with federal, state and SUNY guidelines), after which it will be destroyed.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

Your participation in this research study will be kept confidential to the extent permitted by law. However, it is possible that other people may become aware of your participation in this study. For example, the State University of New York College at Cortland Institutional Review Board may inspect and copy records pertaining to this research:

COSTS FOR PARTICIPATION

There are no costs associated with your participation in this study, other than costs associated with your travel to and from the testing site. These travel costs will not be reimbursed to you. You are responsible for all travel and travel-related expenses.

COMPENSATION FOR PARTICIPATION

There will be no monetary compensation provided for participating in this research.

VOLUNTARY PARTICIPATION

Taking part in this research study is voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty to you.

CONTACT INFORMATION FOR QUESTIONS OR CONCERNS

You have the right to ask any questions you may have about this research. If you have questions, complaints, or concerns or believe you may have developed an injury related to this research, contact Cory Monahan (principal investigator) by phone at 518-755-9260 or by e-mail at cory.monahan@cortland.edu

For questions or concerns about your rights as a research participant, contact the SUNY Cortland Institutional Review Board by email at irb@cortland.edu, or by phone 607-753-2511. If you have questions regarding your rights as a research participant or you have concerns or general questions about the research, contact the SUNY Cortland Institutional Review Board by email at irb@cortland.edu, by phone 607-753-2511, or by mail: Miller Building, Room 206, PO Box 2000, Cortland, NY 13045. You may also call this number if you cannot reach the research team or wish to talk to someone else.

For more information about participation in a research study and about your institutional review board (IRB), a group of people who review the research to protect your rights, please visit the State University of New York (SUNY) College at Cortland IRB's Web site at www2.cortland.edu/offices/irb/. Included on this Web site, under the heading "Information for Research Participants" you can access Federal regulations and information about the protection of human research participants. If you do not have access to the Internet, copies of these Federal regulations are available by calling the SUNY Cortland Institutional Review Board by phone: 607-753-2511 or by email: irb@cortland.edu

I ____ have read the description of the project for which this consent is requested, I understand my rights, and I hereby consent to participate in this study.

____ ________________________

Signature Date

APPENDIX D: Questionnaire

Thank you for your interest in volunteering to participate in the research study titled "The effect of attentional focus instructions on single leg balance performance."

Please respond to the following questions to be sure you meet the necessary criteria for participation in this research study.

1) How old are you?
   ________ years

2) Are you male or female? (circle your answer)

   Male Female

3) Are you currently experiencing trouble with vision, either near or far?
   ________ (Yes or No)

4) Do you currently wear glasses to correct vision?
   ________ (Yes or No)

5) Are you experiencing trouble with dizziness?
   ________ (Yes or No)

6) Do you have any pain or painful movement limitations anywhere in the body (examples: ankle pain, knee pain, hip pain, low-back pain, neck pain, or any other areas of the body)?

   ________ (Yes or No)

7) To the best of your knowledge, do you have any physical condition(s) that may affect your balance and/or posture? If yes, simply respond "yes." You do not need to list or explain the condition(s).
   ________ (Yes or No)

8) What is your weight and height?

   Weight:_______ pounds
   Height: _______ feet ______ inches

9) Do you wear orthotic footwear?
   ________ (Yes or No)

   If Yes, are they custom-made or generic? __________________

   If Yes, do you wear the orthotic(s) in your left shoe, right shoe, or both?____________________

Please sign below to indicate that you responded truthfully and to the best of your knowledge.

Sign here ____

Printed name ____Date __________________

APPENDIX E: Task Instructions

Instructions for your balance task

You are asked to perform a trial of single leg balance standing on the square force plate that the investigator (Cory Monahan) will direct you to. Before performing the task, please read the following instructions. It is important that you understand these instructions and adhere to them throughout the experiment. Cory will not speak any instructions to you. Please do your best to follow these written instructions:

1) If you are wearing long pants and the bottom of the pant legs extend past your ankles and you have not yet rolled them up past your ankles, please do so now. Remove your shoes and socks, as this task will be performed barefoot.

2) Cory will guide you to the platform that you will stand on and which direction to face. You will balance standing on either your right or left leg (determined below) for thirty-five seconds. Cory will inform you when to start by saying "You may begin."

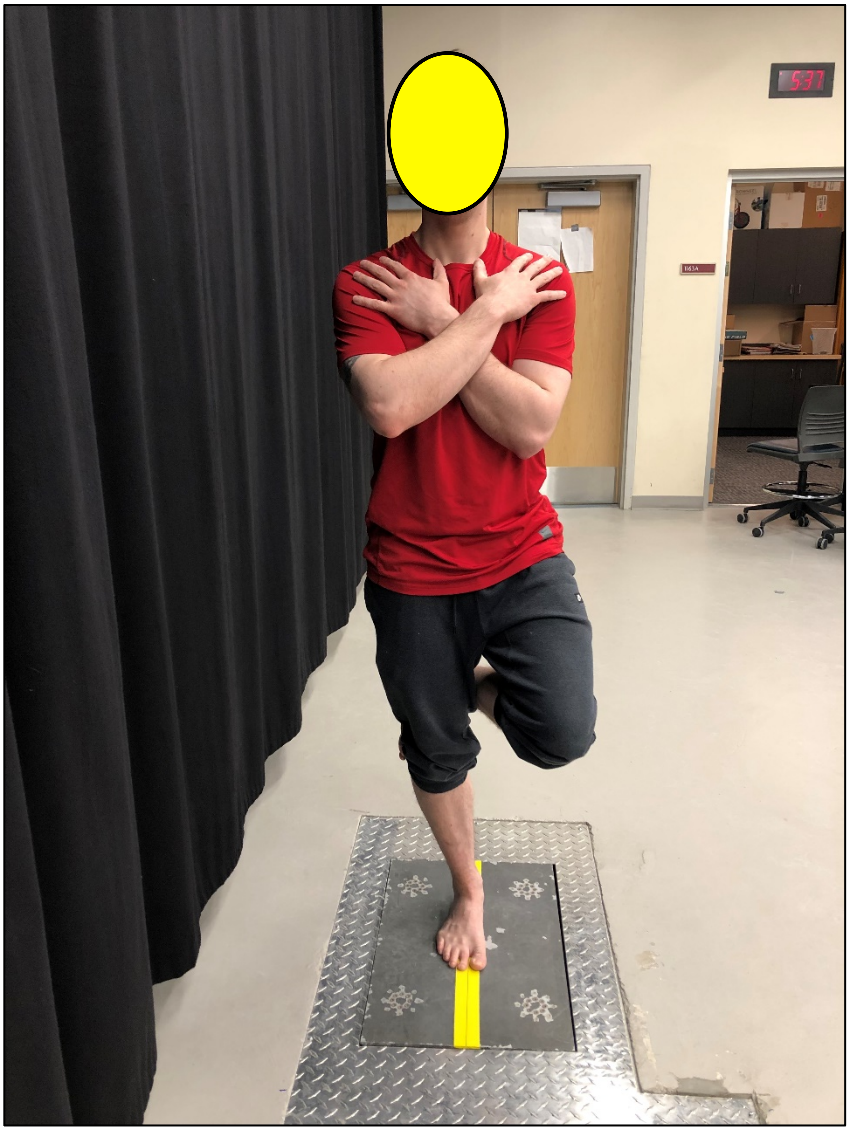
3) Circle either "Left" or "Right" based on the following question:
   If you were to kick a ball on a target, which leg would you use to kick the ball?
   Left Right

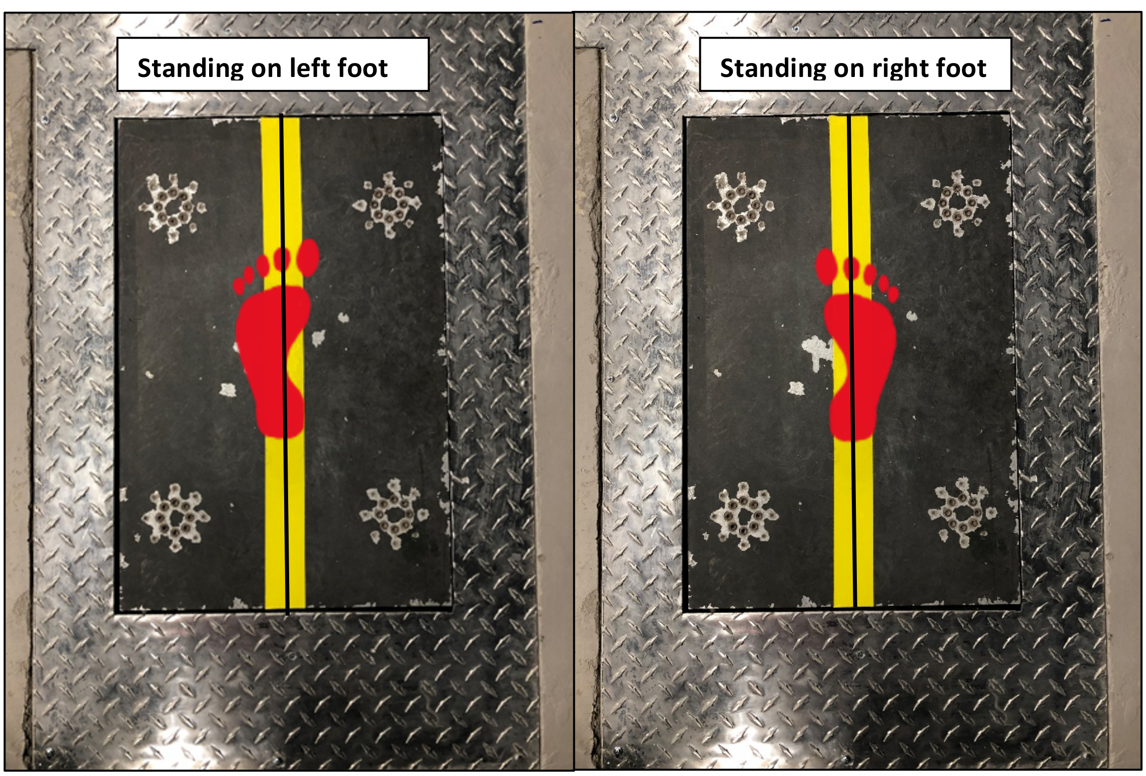
   The answer that you **DID NOT** circle will be the leg you are going to stand on.

4) The balance task procedure:
   -When Cory tells you "You may begin," stand on the determined leg and place the other foot against the back of your knee of the leg you are standing on. Cross your arms loosely across your chest. Look at the red three-inch marker on the floor in front of you.
   -A picture of the form required is on the next page. Be sure to look at the picture so that you understand the task. Be sure position your foot on the line as illustrated. Please note that the line on the platform passes through the heel and under the base of the second toe (see picture on next page).

   -After you begin balancing, Cory will tell you when time begins by saying "Time starts now" and when the trial is over by saying and "You are finished."

5) Your attentional focus instructions are on the last page. Be sure to read and adhere to these instructions while you are performing the balance task. This is very important!




Standing on left foot
Standing on right foot

INT group

Attentional focus instruction:

During the balance task, stand as still as you can. Focus on feeling your heartbeat, and try to count the number of times your heart beats.

Sign your name on the following line if you understand the instructions and will adhere to them for the duration of the balance trial.

Signature____

Hand this document to Cory and he will direct you to the force platform.

EXT group

Attentional focus instruction:

During the balance task, stand as still as you can. Watch the cartoon on the monitor in front of you. Try to count the number of times the cartoon switches scenes.

Sign your name on the following line if you understand the instructions and will adhere to them for the duration of the balance trial.

Signature____

Hand this document to Cory and he will direct you to the force platform.

CON group

Attentional focus instruction:

During the balance task, stand as still as you can.

Sign your name on the following line if you understand the instructions and will adhere to them for the duration of the balance trial.

Signature____

Hand this document to Cory and he will direct you to the force platform.

APPENDIX F

Participant data

Participant	Group	Age	Gender	Height	Weight	BMI	Leg balanced on	Successful attempt?
1	Internal	20	male	70	180	25.88	left	No
2	Internal	20	male	69	197	29.15	left	yes
3	Internal	23	male	75	195	24.42	left	yes
4	Internal	22	male	73	212	28.03	left	yes
5	Internal	23	male	69	195	28.86	left	yes
6	Internal	21	female	61	132	24.99	left	yes
7	Internal	20	female	65.5	140	22.99	left	yes
8	Internal	22	female	63	120	21.30	left	yes
9	Internal	28	female	60	131	25.64	right	yes
10	Internal	19	female	62	116	21.26	left	yes
11	Internal	22	female	66	160	25.88	left	yes
12	Internal	21	male	74	196	25.22	left	yes
13	Internal	19	female	62	160	29.33	left	yes
14	Internal	19	male	71	164	22.92	left	yes
15	Internal	19	female	66	135	21.84	left	yes
16	Internal	19	male	68	183	27.88	left	yes
17	External	19	female	62	145	26.58	right	no
18	External	20	Male	68	165	25.14	left	yes
19	External	19	female	64	135	23.22	left	yes
20	External	19	male	71	185	25.86	left	yes
21	External	19	female	69	150	22.20	left	yes
22	External	19	male	69	160	23.68	left	yes
23	External	20	female	61	145	27.45	right	yes
24	External	21	male	74	192	24.70	right	yes
25	External	20	female	69	175	25.90	left	yes
26	External	20	female	66	180	29.11	left	yes
27	External	21	female	66	135	21.84	left	yes
28	External	23	male	66	161	26.04	left	yes
29	External	21	male	73	170	22.48	right	yes
30	External	21	male	70	135	19.41	left	yes
31	External	22	male	69	165	24.42	left	yes
32	External	20	female	64	155	26.66	left	yes
33	External	22	female	68	180	27.43	left	yes
34	Control	20	male	69	200	29.60	left	no
35	Control	19	male	74	195	25.09	left	yes
36	Control	20	male	68	190	28.95	left	yes
37	Control	19	female	68	195	29.71	left	yes
38	Control	19	male	69	185	27.38	left	yes
39	Control	19	female	67	140	21.97	left	yes

40	Control	19	female	66	115	18.60	left	yes
41	Control	22	male	66	143	23.13	left	yes
42	Control	21	female	67	165	25.90	left	yes
43	Control	23	male	74	197	25.35	left	yes
44	Control	20	female	68	183	27.88	left	yes
45	Control	21	female	63	145	25.74	left	yes
46	Control	20	female	65	132	22.01	left	yes
47	Control	21	female	65	165	27.51	left	yes
48	Control	20	female	62	130	23.83	right	yes
49	Control	22	female	66	143	23.13	left	yes