An external focus of attention is effective for balance control when sleep-deprived

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Abstract:

The purpose of our study was to examine if the beneficial effects of an external focus are effective for balance control when sleep-deprived. Sleep-deprived participants (27 hours awake) completed three blocks of five separate 30 second trials on a dynamic balance board. All participants were given internal, external, and control instruction. For the internal focus trials, participants focused on their feet; whereas, for the external focus trials, participants focused on the balance board. Participants' time in balance was significantly greater during the external focus compared to the internal focus and control. These findings suggest that external focus instructions are effective when participants are sleep-deprived.

Keywords: Sleep-deprivation | balance | external focus | internal focus

Article:

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Original Research

An External Focus of Attention is Effective for Balance Control when Sleep-deprived

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ABSTRACT

International Journal of Exercise Science 11(5): 84-94, 2018. The purpose of our study was to examine if the beneficial effects of an external focus are effective for balance control when sleep-deprived. Sleep-deprived participants (27 hours awake) completed three blocks of five separate 30 second trials on a dynamic balance board. All participants were given internal, external, and control instruction. For the internal focus trials, participants focused on their feet; whereas, for the external focus trials, participants focused on the balance board. Participants' time in balance was significantly greater during the external focus compared to the internal focus and control. These findings suggest that external focus instructions are effective when participants are sleep-deprived.

KEY WORDS: Sleep-deprivation, balance, external focus, internal focus

INTRODUCTION

Chronic sleep restriction and acute sleep deprivation affect many Americans with a substantial proportion of the population reporting less than the recommended seven to nine hours of sleep per night (22). The effects of sleep deprivation on motor and cognitive performance vary from minor to debilitating and can result in decisional impairments that can have critical implications in certain professions. These professions include military personnel, industry-related professions such as long-haul truck drivers or air traffic controllers, and health-care related professionals such as physicians and nurses. In addition, one of the main concerns of sleep-deprivation is the resulting fatigue that negatively affects cognitive and motor performance. Individuals with sleep deprivation have demonstrated poor judgement, imperfect coordination, and slow reaction-time to an extent that is similar to the impairments seen in intoxicated individuals (40). Research has shown that 19, 24, and 48 hours of sleep deprivation can affect basic motor control and postural stability (14, 21, 25). Since balance control is one of the more important functions of the human body (41, 42), it is important to develop interventions that can improve balance control in those suffering from sleep-deprivation.

A variety of studies have explored the effects of sleep deprivation on balance control (1, 7, 9, 10, 17, 20, 21, 25, 28, 30, 32). The general conclusion from these studies is that postural control is negatively affected by sleep deprivation and that a safe intervention to improve balance control is needed. Numerous hypotheses on why sleep-deprived individuals have altered balance control have been suggested, and one of these relates to changes in attention levels (14, 18, 21). Thus, we predict that properly directing an individual's attention may be particularly useful in enhancing balance control when sleep-deprived.

A well-established technique derived from motor behavior research to enhance motor performance and learning is the utilization of an external focus of attention (43, 44). An external focus of attention directs a performer's attention towards the effects of one's movements; whereas an internal focus directs attention towards movement execution (46). The seminal study in this line of research demonstrated that instructing participants to focus on the 'wheels' of a ski simulator, an external focus, resulted in enhanced balance control and learning relative to instructions to adopt an internal focus by directing participants to focus on their 'feet' (46). Subsequently, the benefits of an external focus on balance control have been widely replicated (2, 13, 19, 47). The theoretical basis for the benefits of an external focus is that it allows the performer to behave more reflexively and automatically; whereas, an internal focus constrains the motor system by consciously interfering with previously developed motor movements (constrained action hypothesis) (19, 47, 48).

To our knowledge there are no studies investigating the effects of sleep deprivation on balance control when attentional focus is manipulated. Therefore, the purpose of this study was to examine if an external focus of attention was effective for those who were sleep-deprived. We hypothesized that using an external focus of attention following a period of sleep-deprivation would result in greater balance control compared to an internal focus or no focus of attention instruction, with no differences in balance control when comparing the internal focus and no focus of attention instructions.

METHODS

Participants

Healthy college-aged students were recruited for this study. Participants were excluded if they had any neurological disorder affecting sleep or balance. In total, eight healthy participants (5 males, age = 24.8 ± 4.6 yrs, height = 176.4 ± 8.8 cm, mass = 87.2 ± 22.7 kg; 3 females, age = 25.0 ± 3.5 yrs, height = 70.3 ± 8.33 cm, mass = 168 ± 8.7 kg) volunteered to participate in this study. The institutional ethics committee approved the project and informed consent was obtained prior to commencing the study.

Protocol

All balance testing was completed on a dynamic balance board (Indo Balance Board Trainer, Indian Harbour Beach, FL) which has been previously used to train balance (23). The board is elliptical with a vertical diameter of 74.9 cm and horizontal diameter of 45.1 cm. For all tasks, the board was positioned on a rubber ball inflated to 12.7 cm in height. New to previous balance board research, we attached an inertial sensor (Xsens; Xsens Technology, MA) to the center of the Indo Board to capture changes in Euler angles at a rate of 100 hz (see Figure 1). This modification to the board allowed us to quantify 'time in balance', our dependent variable of interest, in both the anterior-posterior and medial-lateral directions by measuring the time in which the board was +/- 5 degrees from horizontal in either direction. We selected time in balance as our dependent variable since it is consistent with previous research examining balance control with a stabiolometer (2, 4, 36, 46). Time in balance was calculated using custom scripts written in Matlab (Mathworks, Inc., Natick, MA) with greater values indicating superior balance control. A depiction of sample raw data displaying a superior trial and poor trial on the balance board is presented in Figure 2.

Figure 1. Indo Balance Board Trainer used to assess balance control. Xsens technology was attached to the center of the board to quantify time in balance in both the anterior-posterior and medial-lateral directions.

One day prior to testing, all participants were fitted with an Actigraph GT9X Link accelerometer (Actigraph, Pensacola, FL) which they wore throughout testing. The accelerometer was used to determine participants' total sleep time and to verify that each participant remained awake throughout the duration of the study. Following a night of sleep in the participants' home environment (M = 5.16 hrs, SD = 1.06 hrs), participants were asked to wake at 0500h and to report to the laboratory for physiological and cognitive baseline testing at 0600h. Of note, the current study investigating attentional focus and balance board testing (n = 8) was added to a larger sleep-deprivation study containing additional participants (n = 24). Methods and results from our cognitive testing have been previously reported (31) (physiological analyses are ongoing). Briefly, our cognitive data (n = 24) revealed that sleep deprivation was detrimental to cognitive performance. Specifically, during the psychomotor vigilance task (PVT), reaction time increased ($t(23) = -4.78$, $p < .001$) from morning 1 to morning 2. Additionally, participants exhibited increases in lapses ($t(23) = -4.82$, $p < .001$) and false alarms ($t(23) = -2.59$, $p <.05$) from morning 1 (rested) to morning 2 (sleep-deprived). Our subsample for this study ($n = 8$) exhibited similar findings for reaction time and lapses with poorer reaction time ($t(7) = -2.35$, $p = .05$) and significantly more lapses ($t(7) = -2.43$, $p < .05$) when sleep deprived. While no balance testing was done during baseline testing as we did not want to confound our sleep deprivation results with possible learning effects, our cognitive results lend support that sleep deprivation may have also negatively impacted motor performance. After cognitive and physiological baseline testing, participants resumed normal daily activities, but were instructed to refrain from any form of moderate or vigorous intensity physical activity. Participants returned to the laboratory at 2100h. During their time in the laboratory overnight, participants were monitored by experimenters to ensure they remained awake; they were permitted to work on school-related assignments, watch movies, and play video games. Water was available ad libitum, but no alcohol, caffeine, or food was permitted after 2300h. At 0600h following acute sleep deprivation, participants completed a second round of physiological and cognitive testing and then completed the balance testing at approximately 0800h. In total, participants were awake for a minimum of 27 hours before completing the balance testing (0500h on morning 1 to 0800h on morning 2).

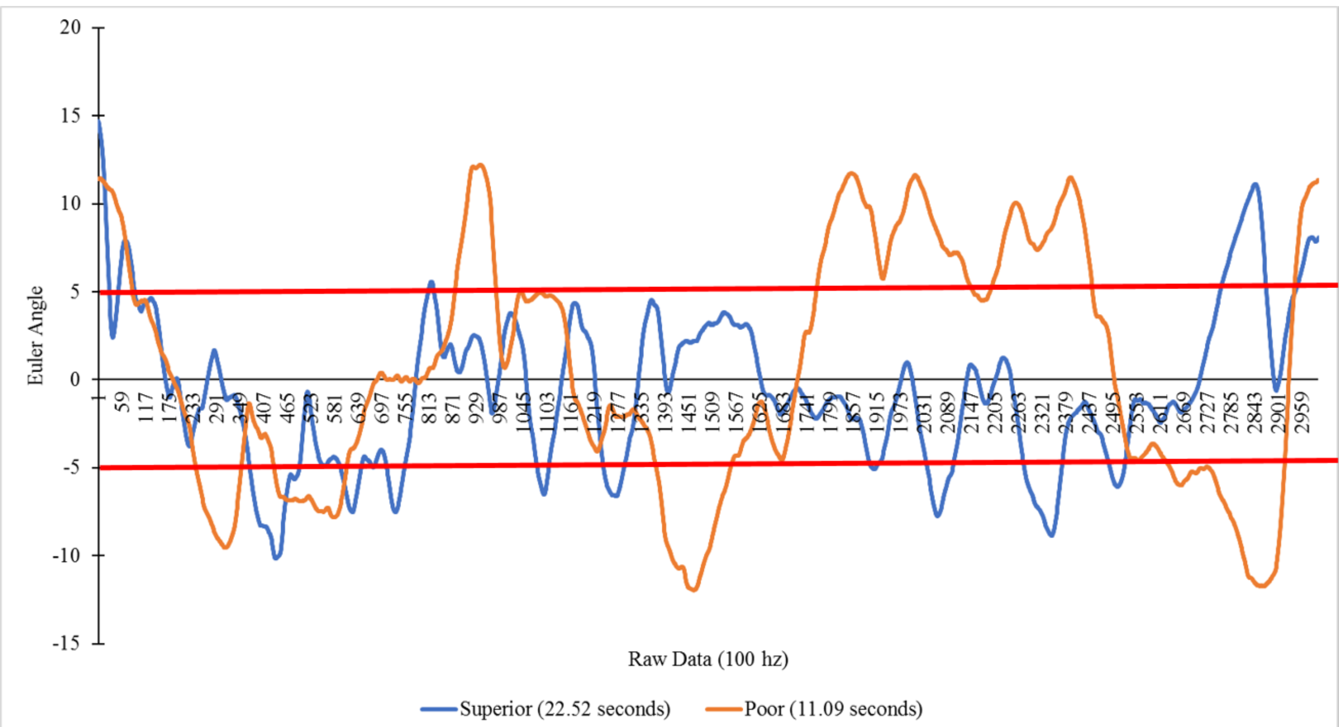

Figure 2. Sample raw data of a superior trial (in blue) and poor trial (in orange) on the balance board. Time in balance was measured be calculating the time the Xsens was within +/- 5 degrees from horizontal (red lines). In this example, the superior trial accrued a time in balance of 22.52 seconds, whereas the poor trial accrued a time in balance of 11.09 seconds (medial-lateral direction).

For the balance testing participants were allowed one minute to stand on the board for familiarization purposes. Participants then completed three blocks of five separate 30-second trials (15 balance trials total), in which participants were given internal, external, or no focus (control) of attention instruction. Congruent with Ducharme et al. (5), condition order was counterbalanced to control for potential order effects. This means that one participant would first complete their control trials, followed by their internal focus trials, and finish with their external focus trials. The next participant, however, would first complete their internal focus trials, followed by their external focus trials, and finish with their control trials. A 30-second break was given between trials and a three-minute break was given between each testing block. For the internal focus trials participants were told to, 'focus on keeping your feet as steady as possible;' whereas, for the external focus trials participants were asked to, 'focus on keeping the board as steady as possible.' Participants were given this instruction only once prior to the start of the appropriate block. Since participants only completed 5 trials, we did not feel that reminders were needed and it was reasonable for participants to adhere to instruction for the 5 trial duration. During the control trials, participants were not given any focus of attention instruction. If the participant was unable to stay on the balance board for the full 30 seconds, the trial was stopped as soon as he or she stepped off the platform and only this data was analyzed. This only occurred on 0.03% of the total trials analyzed (4 of the 120 total trials [8 subjects × 15 trials]), thus we did not analyze this data separately.

Statistical Analysis
Time in balance was averaged across the five trials for the anterior-posterior and medial-lateral directions for each condition. Consistent with previous attentional focus research (26), and to test our theoretically driven predictions (3, 8, 11), simple directional contrasts (6) were used to compare the external focus to both the internal focus and control conditions, and to compare the internal focus to the control condition for each dependent variable. We elected this statistical approach due to our low sample size and that our predictions were based on previous literature. This allowed us to directly test our hypotheses without an omnibus test and subsequent post-hoc tests. We hypothesized that participants' time in balance would be greater during the external focus compared to the internal and control condition, but we predicted no differences for time in balance between the internal focus and control condition (44). Significance was set a priori at an alpha level of $p < .05$.

RESULTS

Our simple contrasts did not reveal any significant differences (all p's > .05) for the anterior-posterior direction. However, and consistent with our predictions, participants' time in balance in the medial-lateral direction was significantly greater during the external focus (M = 17.78, SD = 1.87) compared to the internal focus (M = 16.17, SD = 1.62), F (1, 7) = 4.74, $p < .05$, partial $\eta 2$ = .40, and control condition (M = 14.78, SD = 3.99), F (1, 7) = 3.64, $p < .05$, partial $\eta 2$ = .34. No differences were observed between the internal focus and control condition F (1, 7) = .64, $p > .05$, partial $\eta 2$ = .08 (Figure 3).

DISCUSSION

In the current study, we manipulated attentional focus (internal, external, control) to investigate if an external focus of attention was effective for those who were sleep-deprived. We hypothesized that using an external focus following a period of sleep deprivation would result in greater balance control compared to an internal focus or when no directions with respect to the focus of attention were provided. Consistent with our predictions, an external focus did produce more stable movement when standing on a balance board, significantly improving time in balance in the medial-lateral direction.

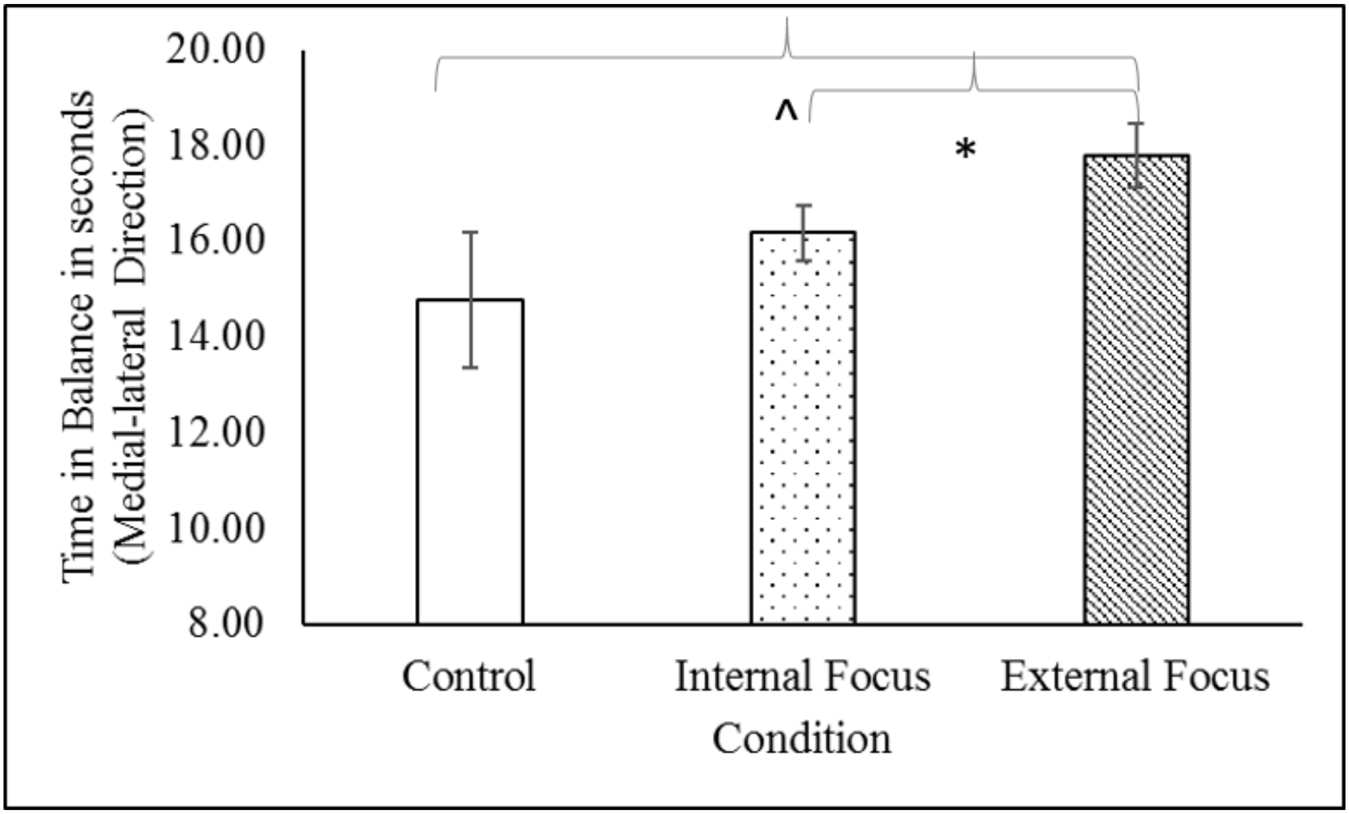

Figure 3. Time in balance in the medial-lateral direction for each condition. *Participants' time in balance was significantly greater during the external focus compared to the internal focus condition (p < .05). ^ Participants' time in balance was also significantly greater during the external focus compared to the control condition (p < .05).

These results are congruent with previous findings that an external focus reduces movement deviations from a starting position with a stabilometer (2, 46). In addition, our findings are consistent with others who have shown that no focus of attention instruction yields similar results to an internal focus (13, 45, 46). Unfortunately, it is unfeasible to truly know what participants focused on without specific focus instruction, but our behavioral data suggests that sleep-deprived individuals may naturally revert to an internal focus when the instructions that are given do not direct attention. This unintended consequence, however, may be ameliorated by directing attention externally, since our data shows that an external focus enhances performance relative to an internal focus or no focus instruction. These findings are important because they demonstrate that using specific instructional cues that guide someone to focus externally is effective for motor performance when sleep-deprived.

The contributions from this study pertain to both the sleep deprivation and balance literature as it highlights the importance of instruction on postural control. Considerable research has investigated the usefulness of balance as a tool to assess fatigue (21, 29), yet there is no standard instruction provided to participants. For example, Sargent et al. (29) instructed participants to 'focus on a target' during assessment, which could be interpreted as an external focus and potentially influence balance control. Thus, we recommend that others carefully select the instructions they provide as our data suggests it plays an important role in resulting balance control. Simply changing one or two words during the administration of a postural assessment can influence balance control when sleep-deprived.

In addition, balance control is often used as a proxy to determine the current state of the motor system, as it is a homeostatic mechanism which integrates input from the eyes, vestibular system, joints, and muscles to operate effectively (35). Our finding that an external focus is effective for balance control when sleep-deprived suggests that it may augment the regulation of these various systems, which has implications for military personnel, industry-related professions, and health-care related professionals. Some professions (e.g., firefighters) require physically demanding activity in which balance control is fundamentally important (33), thus an external focus could potentially minimize some of the associated human-error related incidents in these professions. Further, other techniques which have been shown to positively affect cognitive performance following sleep deprivation, such as administering caffeine (27, 34, 39) or other stimulants like dextroampehtamine (12) can be detrimental to subsequent sleep recovery (24), making an external focus a safe, cost-effective, and easily administered technique for aiding motor performance.

One potential mechanism for our findings is the reduced attentional demands attributed to an external focus when rested (47). While we did not implement a secondary task to assess attentional demands, we reason that there were more attentional resources available to regulate the system and aid in the control of balance when performers adopted an external focus. Another potential mechanism, but was not directly tested in this study, would be greater neuromotor efficiency when an external focus was adopted. Vance et al. (38) keenly demonstrated that when rested an external focus resulted in faster movements (experiment 1) and reduced integrated EMG activity (experiment 2) during a biceps curl when an external focus compared to an internal focus was adopted. Similar findings for an external focus when rested have been exhibited in dart throwing (16) and basketball free-throw shooting (50) suggesting an external focus is more neuromuscularly efficient. Considering our improvements in balance control when participants adopted an external focus while sleep-deprived, we reason a similar mechanism could account for our changes, but further investigation is warranted. Future work should consider using more sensitive measures of postural control such as time-to-contact, mean velocity, and nonlinear metrics such as Sample Entropy during a more ecologically valid task. For example, participants could be asked to stand on a force plate while reaching for an object to better represent motor tasks completed when sleep-deprived. Likewise, further clarification and standardization of body posture (feet placement, trunk position, etc.) would supplement our understanding of attentional focus on balance performance when sleep-deprived. It would also be valuable to explore the influence of attentional focus for older adults who are at higher risk of falling than young adults (37). Considering Chiviacowsky, Wulf, and Wally (2) have demonstrated the beneficial effects of an external focus for balance performance in older adults when rested, these results could be supplemented in older adults who also report shortened sleep durations (15). Further, it would be useful to explore the effects of an external focus on motor performance in those enduring chronic sleep deprivation (e.g., less than four hours of sleep for consecutive time periods), or for those who are prone to experiencing longer durations of sleep deprivation (e.g., 36 hours) and compare the effectiveness of attentional focus strategies with other commonly used techniques, such as naps, stimulants, and caffeine to improve performance.

One limitation of this study is that we did not include a comparison group of participants who underwent a full night's sleep. Thus, we were unable to compare the effectiveness of an external focus on our balance control between rested and sleep-deprived individual. Further, we did not test participants' balance on morning one which prevented us from determining the extent to which sleep deprivation hindered balance control in our sample of participants. However, this decision was made a priori because we did not want to elicit any learning effects by having participants complete the balance tasks multiple times. One solution for future research would be to test participants on separate days (rested versus sleep-deprived) to minimize learning and directly compare the effects of attentional focus in both states. Albeit these limitations and our small sample size, this is the first study to demonstrate the effectiveness of an external focus of attention on balance control for sleep-deprived individuals. Our data provides a foundation for future research interested in examining attentional focus in conjunction with sleep deprivation. The results from this study are in support of and complement previous research demonstrating the beneficial effects of an external focus on balance control in rested individuals (2, 13, 19, 48, 49). Our results indicate that an external focus is effective when participants are sleep-deprived as measured by time in balance, relative to an internal focus or when no focus of attention is provided. Thus, we recommend that performers direct their attention externally during the execution of motor tasks when sleep-deprived.

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