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Effects of Attentional Focus and Dual-tasking on Conventional Deadlift Performance in Experienced Lifters

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ABSTRACT

Background: Previous attentional focus literature suggests that adopting an external focus (EF) results in greater force production through a variety of mechanisms. **Objective:** The purpose of the present study was to examine the effects of attentional focus and dual-tasking when performing heavily loaded barbell movements that are specific to strength-based sports. **Method:** Fifteen resistance-trained males (age = 23.3 ± 3.4 years) reported to the laboratory for three visits. The first visit consisted of a five-repetition maximum (5RM) test on the conventional deadlift. During the subsequent sessions, the participants performed a total of twelve single conventional deadlift repetitions while adopting an internal focus (IF), an external focus (EF), or while performing the cognitive task (COG). The IF and EF consisted of focusing on activating the quadriceps and maintaining a straight bar path, respectively. The COG consisted of counting the total occurrence of two single-digits in a sequence of three-digit numbers, separately. Three-dimensional motion capture and force platforms were used to collect kinematic and kinetic data. **Results:** No significant differences were found between the IF, the EF and the COG for lift duration, peak barbell velocity, peak vertical ground reaction force, area of 95% confidence ellipse, peak hip moments and peak hip powers. Adopting an EF significantly reduced variability of the barbell trajectory and centre of pressure (COP) in the anterior-posterior direction. Mean velocity of COP was also significantly lower for the EF. **Conclusion:** Our findings suggest that adopting an EF may lead to greater postural stability when performing heavily loaded barbell movements.

Key words: Cognition, Attention, Athletic Performance, Cues, Movement, Posture, Resistance Training, Weight Lifting

INTRODUCTION

Elite level competition in almost any discipline is often won within small margins. From implementing complex periodization strategies to utilizing the latest equipment, athletes are always looking for an edge over their competition. Over the past two decades, the attentional focus literature has shown that where an individual directs their attention during goal-directed action can affect motor learning and performance (Wulf, 2013). More specifically, directing one's focus on movement effects (i.e. external focus) as opposed to one's own body movements (i.e. internal focus) yields superior motor learning and performance (Wulf & Dufek, 2009). This phenomenon has been well studied in a wide variety of sport specific skills (Wulf, 2013). Examples of sports that have been studied in the attentional focus literature include golf (Bell & Hardy, 2009; Kearney, 2015; Poolton, Maxwell, Masters, & Raab, 2006; Wulf & Su, 2007), dart throwing (Lohse, Sherwood, & Healy, 2010; Marchant, Clough, & Crawshaw, 2007) and basketball (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002; Zachry, Wulf, Mercer, & Bezodis, 2005), to name a few.

The consistency in which an EF yields superior performances relative to an IF across a variety of sport specific and non-sport specific tasks is commonly explained using the constrained action hypothesis. McNevin et al. (2003) proposed that consciously attending to one's movements (i.e. IF) may interfere with the automaticity of motor control processes that regulate movement, whereas focusing on movement effects (i.e. EF) may promote the automaticity of said motor control processes. Polskaia et al. (2014) extended this line of thought by comparing the effects of a continuous cognitive task with an EF and IF during quiet standing. The continuous cognitive task showed the greatest reduction in sway amplitude and variability, and thus superior postural control compared to the attentional focus conditions. This finding was attributed to the continuous cognitive task diverting one's attention away from their posture altogether, leading to even less interference of the automatic processes related to posture than an EF. Furthermore, the continuous nature of the cognitive task may provide a unique advantage regarding sport performance as previous research suggests that athletes primarily use an IF

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and tend to shift their focus between IF and EF during skill execution (Porter, Nolan, Ostrowski, & Wulf, 2010; Porter, Wu, & Patridge, 2010). Though the effects of different attentional focuses are well studied, research examining the effects of a continuous cognitive task while simultaneously executing a sport-specific skill is limited and merits further examination.

Though the literature pertaining to attentional focus and force production is sufficient in making preliminary suggestions when it comes to resistance training, coaches and athletes participating in strength-based sports (e.g., Strongman, Olympic Weightlifting, Powerlifting, etc.) may be hesitant in adopting these suggestions given the lack of exercise specificity. At the time of the present work, there are few studies that have examined the influence of attentional focus on force production that are similar to events typically seen in strength-based sports (e.g. Marchant, Greig, & Scott, 2009; Snyder & Fry, 2012). For example, Marchant et al. (2009) reported greater peak net joint torque for the EF condition relative to an IF condition during an isokinetic elbow flexion task. Though the task was performed at similar intensity to what is typically seen in strength-based sports, the task only involved the coordination of a single joint. Moreover, while the series of vertical jump studies completed by Wulf and Colleagues (Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010; Wulf, Zachry, Granados, & Dufek, 2007) showed greater vertical jump heights derived from larger vertical ground reaction forces resulting from an EF, the task lacked any manipulation of an external load (e.g. barbell, dumbbell, atlas stone, etc.). Previous studies that used exercise specific tasks to examine the effects of attentional focus were completed without the context of sport performance. Consequently, these attentional focus studies used loading intensities that were much lower than what is typically used in competition (e.g. Marchant et al. (2011) used 75% of one repetition maximum to assess muscular endurance, Calatayud et al. (2016) used between 20-80% of one repetition maximum and Snyder & Fry (2012) used 20-80% of one repetition maximum to assess changes in muscle activation).

The purpose of this experiment was to examine the effects of attentional focus and a continuous cognitive task on heavily loaded conventional deadlift performance in experienced lifters. It was hypothesized that subjects simultaneously performing the COG would exhibit the greatest conventional deadlift performance (i.e. Smaller standard deviation in barbell position for the anterior-posterior direction, greater peak barbell velocity for the inferior-superior direction, greater peak vertical ground reaction force (pVGRF), a shorter lift duration and a greater hip extensor power) when compared to an EF followed by an IF. Similarly, it was also hypothesized that subjects performing the COG would exhibit the greatest postural stability (i.e. Smaller COP area, smaller COP standard deviation and greater COP velocity in the anterior-posterior direction) (Polskaia, Richer, Dionne, & Lajoie, 2014; Richer, Saunders, Polskaia, & Lajoie, 2017) leading to greater force production (Chulvi-Medrano et al., 2010) when compared to an EF followed by an IF.

METHOD

Experimental Approach to the Problem

Participants visited the laboratory once per week for a total of 3 visits. During the first visit, participants completed a repetition maximum of 5 repetition or less. Using Baechle et al. (2000)'s one repetition maximum table, an estimated 1 repetition maximum was calculated and used to establish the appropriate relative intensity (i.e. 87% of 1 repetition maximum) for the experimental trials. This first visit allowed the investigators to more accurately gauge the current strength of the participants.

During the subsequent visits, participants performed twelve single repetitions at 87% of their 1 repetition maximum after hearing the general task instructions and the instructions specific to a given experimental condition. Kinetic and kinematic data were collected for the lower body joints and the barbell using three-dimensional motion capture. The second and third sessions were identical apart from the randomized condition order. The sessions were performed one week apart from each other. All participants were asked to avoid vigorous exercise over the three-week period and to specifically refrain from exercises involving the lower back and lower body 24hrs prior to each session.

Subjects and Design of Study

Fifteen young adult males between the ages of 18 and 30 ($n = 15$, body mass = 89.4 ± 13.1 kg, age = 23.3 ± 3.4 years) were recruited for this cross-sectional study. An a priori G-power analysis with an Alpha of 0.05 and a power of 0.80 for a multiple variables design revealed that 16 participants were needed to get an actual power of.81. A convenience sample was used given the scarcity of individuals that were able to meet the following performance criteria: All participants were required to have a conventional deadlift 1 repetition maximum of at least twice their current bodyweight and have a minimum of two years of conventional deadlift experience (Table 1). Moreover, participants were in good general health and did not experience any musculoskeletal injuries at least 6 months prior to data collection. Lastly, all participants provided written informed consent at the start of the first session. This study was approved by the University of Ottawa Research Ethic Board.

Procedure

Repetition maximum

Prior to performing the repetition maximum protocol, participants were allotted an optional 10-minute period to perform a self-directed warm-up (e.g. Myofascial release using a foam roller, dynamic stretching, etc.). Using the estimated conventional DL 1RM provided by the participant on the athletic history questionnaire, the investigator calculated the appropriate load for the following relative intensities: 72%, 77%, 82%, 87%. Participants were then instructed to warm-up to 70% of their 1RM for three repetitions, then 75% of their 1RM for two repetitions and lastly 80% for a single repetition. The first attempt at a 5-repetition maximum was performed at 87% of their 1RM. If the attempt was successful, with the aid of the participant's feedback, the investigator increased the load by up to 5% on the subsequent attempt. If the attempt was unsuccessful, the participant was offered an opportunity to reattempt the same load. If the participant declined the offer, the investigator used the attempt with the highest load to calculate the estimated 1RM using Baechle et al. (2000)'s one repetition maximum chart. Participants were given up to 5 minutes of rest between all sets, and all lifts were performed in accordance with USAPL rules and regulations (2001).

Equipment and apparatus

Upon entering the lab for the second and third session, participants were outfitted with reflective markers on the: upper back (T2, left and right acromioclavicular joint); Lower back (left and right aspect of L5, pelvis cluster over S1, left and right posterior superior iliac spines); left and right thigh (medial aspect of the epicondyles of the knee, cluster placed posteriorly mid-thigh); left and right shank (cluster placed posteriorly mid-shank); and left and right foot (medial malleolus, lateral malleolus, superior aspect of the first metatarsal, superior aspect of the fifth metatarsal, calcaneus). An additional set of reflective markers were used solely for calibration and were removed prior to starting the warm-ups sets leading into the twelve trials. A total of forty-three 14 mm reflective markers were placed on the participant (37 positional markers and 6 calibration-only markers, Figure 1) and three additional 14 mm reflective markers were placed on the barbell (1 at each end of the barbell and 1 on top of a weight plate loaded onto the barbell).

Centre of pressure, ground reaction forces and moments were collected at a sampling rate of 1000 Hz by having participants stand with one foot on each of the two force platforms (OR6-6-1000, Watertown, MA, USA; OR6-7-1000, Watertown, MA, USA). Marker position data were collected at a frequency of 100 Hz using a 3-dimentional motion capture system consisting of thirteen reflective infrared cameras (Oxford Metrics, Tustin, CA, USA). Force platform data and marker position data were synchronized both temporally and spatially using Nexus software (Vicon, Centennial, CO, USA).

Participants performed all lifts without shoes (i.e. barefoot, socks), but were permitted to use chalk. The use of a lifting belt was mandatory during the repetition maximum protocol and for all experimental trials. Only lifting belts that were 10 mm in thickness and in accordance with USAPL rules (2001) were permitted. Furthermore, all participants used a 20 kg Ohio Power Bar (Rogue, Ohio, USA) that is typically used in competition.

Table 1. Descriptive characteristics of participants

Characteristics	Participants (n = 15)
Body-mass (kg)	89.4 ± 13.1
Height (m)	1.8 ± 0.07
BMI (kg/m²)	27.6 ± 2.6
Age (y)	23.3 ± 3.4
Resistance Training Experience (y)	5.9 ± 4.1
Experience with Conventional Deadlift (y)	4.2 ± 2.2
Estimated 1RM (kg)*	215.1 ± 27.2

*Estimated 1RM were based on the 1RM protocol performed during the first session Values are mean ± standard deviation (SD) BMI = body mass index

Attentional focus and the cognitive task

Using the estimated 1RM acquired from the repetition maximum protocol, the investigator recalculated the relative intensities used in the first session (i.e. 72%, 77%, 82%, 87%). Participants were once again allotted the optional 10-minute period to perform a self-directed warm-up and were given the same instructions for the submaximal deadlift warm-up. Prior to performing each trial, the investigator gave the participant the following general instructions: "Once you are given the start signal, you are to step onto the platform and perform one conventional deadlift repetition as though you were attempting a new 1RM.".

The appropriate focus instructions or cognitive task instructions were given after the general instructions. For the internal focus condition, participants were instructed: "For this trial, just focus on activating your quadriceps to drive the barbell off the floor.". For the external focus condition, participants were instructed: "For this trial, just focus on moving the barbell in a straight and vertical bar path.". After completing the attentional focus trials, participants were asked for a subjective rating (i.e. 0-100%) of how much of their attention was directed at the focus instructions during the trial. Trials with ratings of 50% or less were removed from the dataset.

For the cognitive task, participants were instructed to silently count the frequency of two pre-selected digit (i.e. 0-9), which was verbalized in a pre-recorded 3-digit number sequence, separately. The numbers were presented every two seconds and the duration of the number sequence matched that of the trial length (i.e. the number sequence started when the participant stepped onto the force platforms and ended once the bar returned to the starting position). Three different number sequences were used to prevent participants from memorizing the sequences. The use of counting aids (e.g. fingers, toes, etc.) was prohibited. After completing the cognitive task trials, participants were asked for the frequency at which the two pre-selected digits were presented. Given that the total number of errors was 6 or greater, the trial was removed from the data set.

Biomechanical Analysis

Visual3D software (Version 4, C-motion, Inc., Germantown, MD, USA) was used to create a linked-segment model based on standing calibration trials and specific anthropometric measures. The model was constructed from uniformly distributed geometric solids available in Visual3D along with anthropometric data provided by Dempster (1955). Specifically, right circular conical frustrums were used to model the feet, shanks and thighs; whereas the pelvis and thorax were modelled by elliptical cylinders. This linked-segment model was then applied to each motion trial. Motion trials were then trimmed such that only the concentric phase of each lift was included for analysis. The start of a lift was defined by the instance in which the barbell's upward velocity was greater than 0. The end of the lift was when the barbell reached a zero upward velocity and reached its maximum vertical position. Marker data and ground reaction force data were filtered using a digital lowpass Butterworth filter at 6 Hz and 10 Hz, respectively (Robertson & Dowling, 2003). Visual3D computed the ankles, knees and hips joint angular velocities, net joint moments of force, net joint powers and barbell kinematics (i.e. position & velocity) using inverse dynamics. Given the small contribution of the ankle and knee joints (see figure 2, 3 & 4), kinetic and kinematic measures about the ankle and knee joints were excluded from further analysis. The remaining dependent variables (i.e. kinetic measures about the hip & barbell kinematics) were then extracted for statistical analysis. Force platform data were exported to MatLab (The MathWorks, Natick, MA, USA) to extract variables concerning centres of pressure.

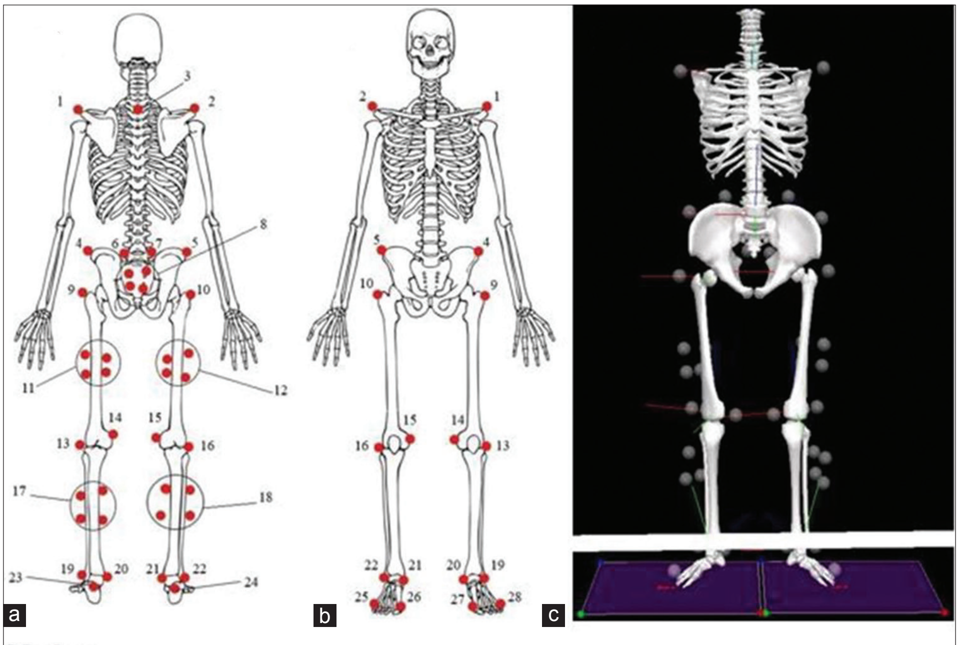
Statistical Analyses

Due to the lack of visibility of marker clusters located on the posterior side of the right leg, data were discarded for one participant resulting in these statistical analyses to be conducted on 14 participants. First, a two-way analysis of variance (ANOVA) was used to determine if there were significant differences between sessions for each condition. Once it was confirmed that there were no significant differences between sessions ($p>0.05$), a separate repeated measures ANOVA on condition (i.e. Internal focus, External focus, Cognitive Task) was used for each of the dependent variables (see results). Fischer's least significant difference post-hoc analysis was used to determine the location of significance. Statistical significance was set at $p < 0.05$. Mauchly's test of sphericity was performed and, when necessary, Greenhouse-Geisser corrections were reported. A total of 13 statistical tests were performed (i.e. one for each dependent variable).

RESULTS

Lift Duration

Only the concentric portion of the lifts were considered for lift duration. The separate repeated measures ANOVA revealed no main effect of condition for lift duration ($F(2,56) = 2.78$, $p > 0.05$, $\eta^2 = 0.355$, Table 2 and Figure 5). However, a trend



Markers
1. Left Acromioclavicular Joint (C&T)
2. Right Acromioclavicular Joint (C&T)
3. T2 (C&T)
4. Left Iliac Crest (C)
5. Right Iliac Crest (C)
6. Left Lateral Aspect of L5 (C&T)
7. Right Lateral Aspect of L5 (C&T)
8. Pelvis Cluster (C&T)
9. Left Greater Trochanter (C)
10. Right Greater Trochanter (C)
11. Left Thigh Cluster (C&T)
12. Right Thigh Cluster (C&T)
13. Left Lateral Femoral Epicondyle (C)
14. Left Medial Femoral Epicondyle (C)
15. Right Medial Femoral Epicondyle (C&T)
16. Right Lateral Femoral Epicondyle (C&T)
17. Left Shank Cluster (C&T)
18. Right Shank Cluster (C&T)
19. Left Lateral Malleolus (C&T)
20. Left Medial Malleolus (C&T)
21. Right Medial Malleolus (C&T)
22. Right Lateral Malleolus (C&T)
23. Left Calcaneus (C&T)
24. Right Calcaneus (C&T)
25. Right Fifth Metatarsal (C&T)
26. Right First Metatarsal (C&T)
27. Left First Metatarsal (C&T)
28. Left Fifth Metatarsal (C&T)

Figure 1. (a) Posterior and (b) anterior view of a skeletal model with both calibration (c) and tracking (T) markers. (C) Anterior view of the Visual3D model

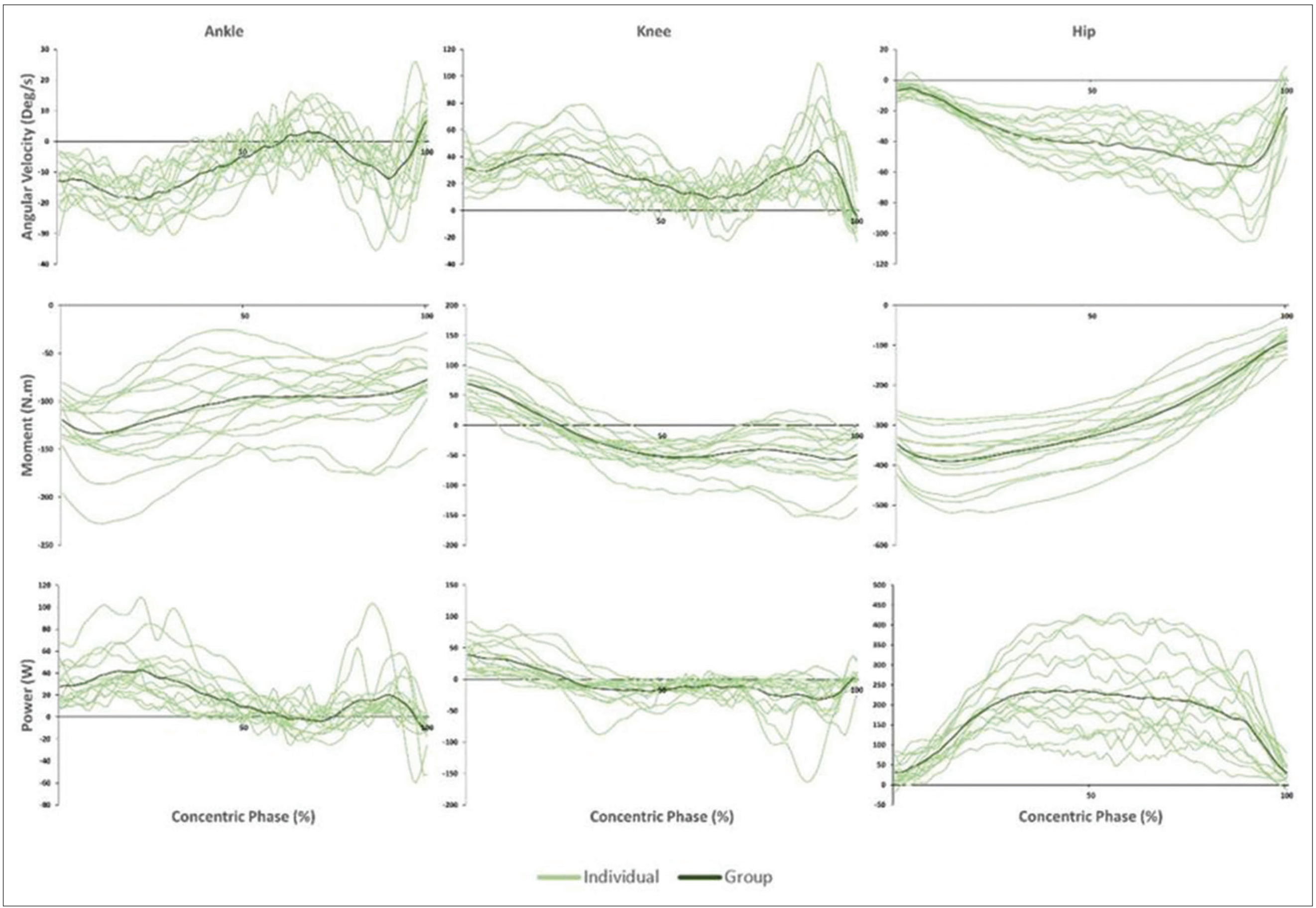


Figure 2. Individual participant mean and group mean data (n = 14) during both experimental sessions for the internal focus condition. Angular velocities, net joint moments and powers are displayed as a function of the concentric phase of the conventional deadlift for the first, second and third row, respectively. Each column corresponds to a different lower body joint on the left side (i.e. Ankle joint for the left column, Knee joint for the middle column and Hip joint for the right column). Positive moments at the hip are flexor; positive moments at the knee are extensor; positive moments at the ankle are dorsiflexor

for a faster lift duration for COG when compared to EF was observed ($p = 0.071$).

Peak Barbell Velocity

The separate repeated measures ANOVA revealed no main effect of condition for peak barbell velocity in the inferior-superior direction ($F(2,56) = 1.08$, $p = 0.345$).

Standard Deviation of the Barbell Position

There was a main effect of condition for the standard deviation of the barbell position in the anterior-posterior direction ($F(2,56) = 4.40$, $p = 0.017$, $\eta^2 = 0.928$, Figure 6). Post-hoc analysis revealed greater standard deviation of the barbell position in the AP direction for IF and COG when compared to the EF ($p < 0.05$). No significant differences were found between the SD of the barbell in the AP direction when comparing IF with COG ($p > 0.05$).

Peak Vertical Ground Reaction Force

There was no main effect of condition for pVGRF ($F(2,56) = 2.46$, $p > 0.05$, $\eta^2 = 0.338$). However, a trend for a smaller pVGRF for EF when compared to IF and COG was observed ($p = 0.095$).

Area of 95% Confidence Ellipse

There was no main effect of condition for Area ($F(2,56) = 2.73$, $p > 0.05$, $\eta^2 = 0.689$). However, a trend for a less sway amplitude was observed for EF condition when compared to IF and COG ($p = 0.074$).

Mean Velocity of Centre of Pressure

There was no main effect of condition for mean velocity of centre of pressure in the medial-lateral direction ($F(2,56) = 1.980$, $p = 0.148$). However, there was a main effect of condition for the mean velocity of centre of pressure in the anterior-posterior direction ($F(2,56) = 3.54$, $p = 0.036$, $\eta^2 = 0.885$). Post-hoc analysis revealed greater velocity for the COG condition when compared to EF condition ($p > 0.05$).

Standard Deviation of Centre of Pressure

There was no main effect of condition for SD of COP in the medial-lateral direction ($F(2,56) = 0.030$, $p = 0.971$). However, there was a main effect of condition for SD of COP in the anterior-posterior direction ($F(2,56) = 5.47$, $p = 0.007$, $\eta^2 = 0.917$). Post-hoc analysis revealed less sway variability for the EF con-

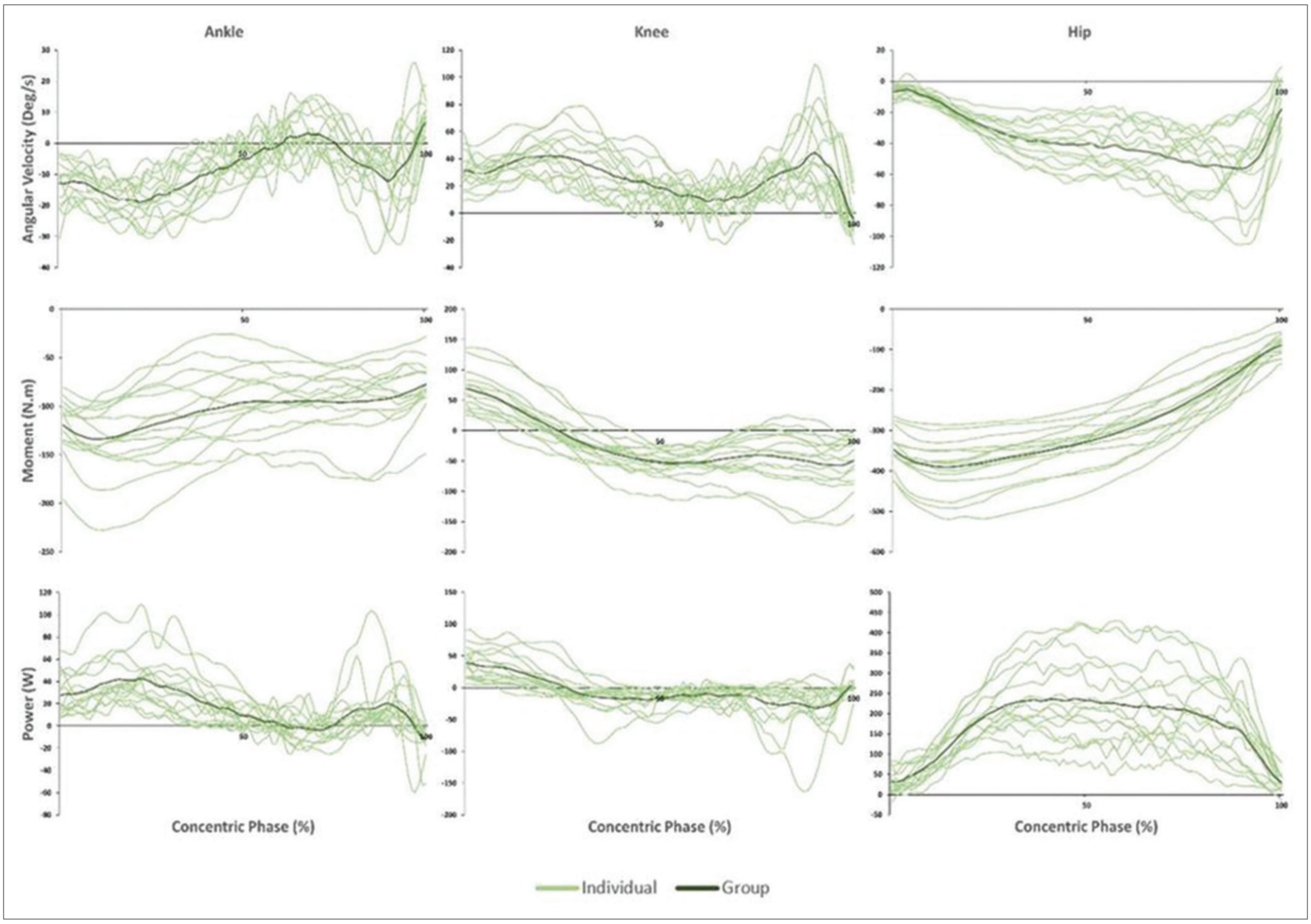


Figure 3. Individual participant mean and group mean data (n = 14) during both experimental sessions for the external focus condition. Angular velocities, net joint moments and powers are displayed as a function of the concentric phase of the conventional deadlift for the first, second and third row, respectively. Each column corresponds to a different lower body joint on the left side (i.e. Ankle joint for the left column, Knee joint for the middle column and Hip joint for the right column). Positive moments at the hip are flexor; positive moments at the knee are extensor; positive moments at the ankle are dorsiflexor

dition when compared to IF and COG ($p < 0.05$). There was no significant difference observed between IF and COG ($p > 0.05$).

Left Peak Hip Moment

There was no main effect of condition for left peak hip moment ($F(2,56) = 1.45$, $p = 0.242$, Figure 7). There was also no main effect of condition for the right peak hip moment ($F(2,56) = 1.28$, $p = 0.285$, Figure 8).

Right Peak Hip Power

There was no main effect of condition for left peak hip power ($F(2,56) = 0.996$, $p = 0.376$). There was also no main effect of condition for the right peak hip power ($F(2,56) = 1.045$, $p = 0.358$).

DISCUSSION

Attentional Focus Effects on Conventional Deadlift Performance

The purpose of the present work was to examine the effects of attentional focus and dual-tasking, using a COG, on conventional deadlift performance in experienced lifters. It was hypothesized that utilizing a COG would yield the most efficient (i.e. smaller standard deviation in barbell position for the anterior-posterior direction) and effective (i.e. greater peak barbell velocity for the inferior-superior direction, greater pVGRF, a shorter lift duration, greater hip extensor power) conventional deadlift performance followed by an EF and then an IF. Similarly, we hypothesized that utilizing a COG would also result in the greatest postural stability (i.e. smaller COP area, smaller COP standard deviation and greater COP velocity in the anterior-posterior direction) when performing the conventional deadlift followed by an EF and then an IF. The results indicate attentional focus and dual-tasking effects, with respects to effectiveness and efficiency, diminish when conventional deadlifts are performed at intensities close to an individual's one repetition maximum. However, the present work does provide some evidence to suggest that adopting an EF may aid in anterior-posterior barbell positioning and overall postural stability.

In contrast to our first hypothesis, the findings of the present work revealed no significant differences between adopting an EF, IF, or utilizing a cognitive task with regards to the effectiveness of conventional deadlift performances at high

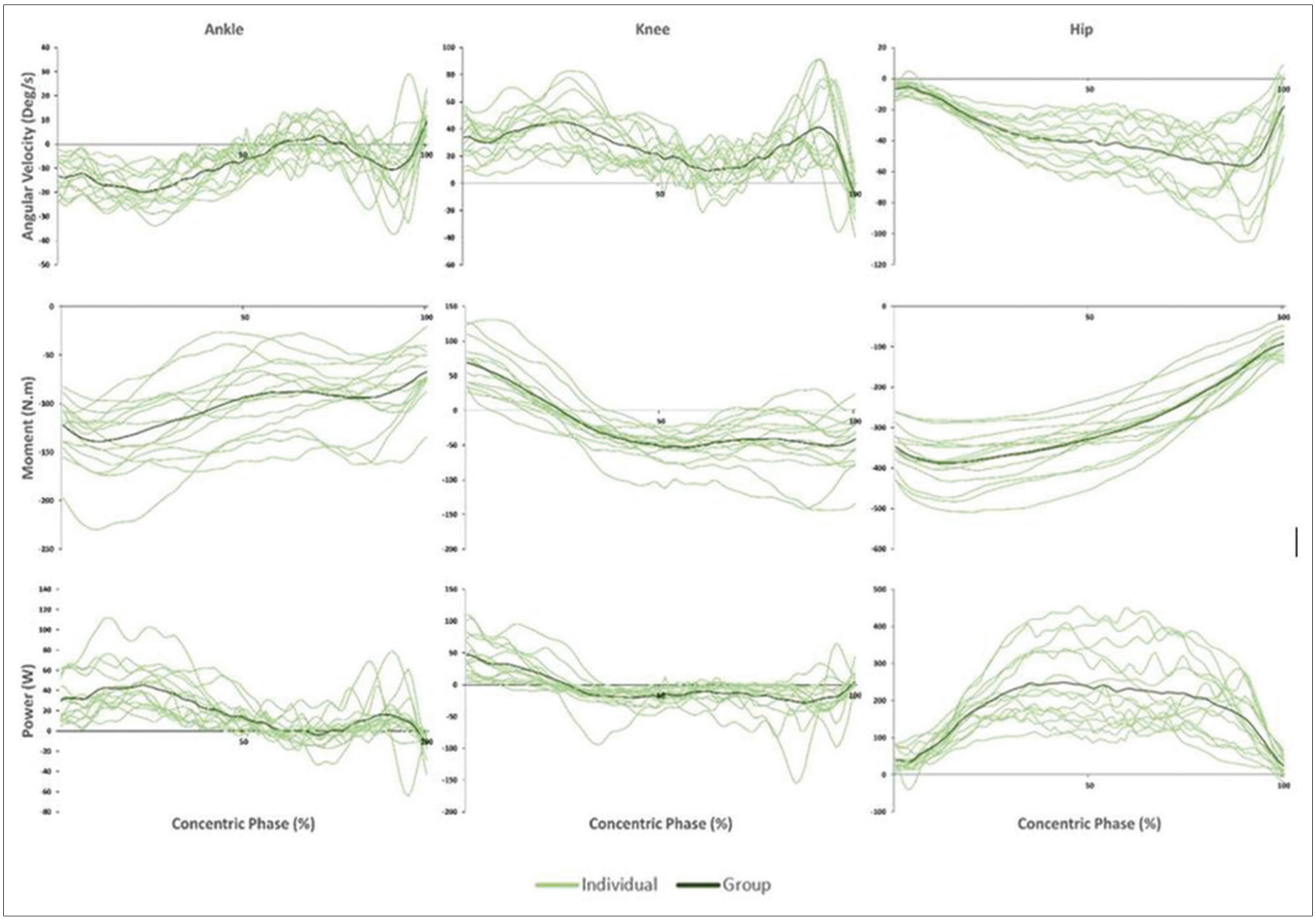


Figure 4. Individual participant mean and group mean data (n = 14) during both experimental sessions for the cognitive task condition. Angular velocities, net joint moments and powers are displayed as a function of the concentric phase of the conventional deadlift for the first, second and third row, respectively. Each column corresponds to a different lower body joint on the left side (i.e. Ankle joint for the left column, Knee joint for the middle column and Hip joint for the right column). Positive moments at the hip are flexor; positive moments at the knee are extensor; positive moments at the ankle are dorsiflexor

Table 2. Mean and standard deviation (SD) of each condition across all outcome measures

Outcome Measure	Internal	External	COG
Lift Duration (s)	2.50 ± 0.60	2.65 ± 0.91	2.48 ± 0.64
Peak Barbell Velocity z (m/s)	0.39 ± 0.11	0.37 ± 0.11	0.38 ± 0.11
SD of Barbell Position y (cm)	1.78 ± 0.53	1.57 ± 0.56	1.78 ± 0.60
Vertical Peak Ground Reaction Force (N)	2876 ± 371	2869 ± 371	2875 ± 377
Area (cm²)	36.61 ± 12.23	32.43 ± 11.61	37.20 ± 14.03
Mean Velocity COPx (cm/s)	7.38 ± 3.33	7.27 ± 3.16	7.06 ± 2.56
Mean Velocity COPy (cm/s)	7.51 ± 1.97	7.26 ± 1.84	7.68 ± 2.01
SD of COPx (cm)	1.09 ± 0.32	1.08 ± 0.24	1.09 ± 0.31
SD of COPy (cm)	2.10 ± 0.52	1.86 ± 0.57	2.11 ± 0.63
Left Peak Hip Moment (N·m)	–395 ± 69	–393 ± 71	–392 ± 69
Right Peak Hip Moment (N·m)	–393 ± 71	–392 ± 66	–391 ± 69
Left Peak Hip Power (N·m)	332 ± 97	327 ± 103	336 ± 101
Right Peak Hip Power (N·m)	340 ± 89	329 ± 92	333 ± 95

Values are mean ± standard deviation (SD). z = inferior-superior direction. y = anterior-posterior direction. COP = centre of pressure
COG = cognitive

intensity loads (i.e. 87% of 1RM). Despite a large body of literature (e.g. Chiviacowsky, Wulf, & Ávila, 2013; Kal, Van Der Kamp, & Houdijk, 2013; Totsika & Wulf, 2003; Wulf, 2013; Wulf, Shea, & Park, 2001; Wulf & Su, 2007; etc.) indicating a robust performance advantage associated with adopting an EF relative to an IF in other sporting domains,

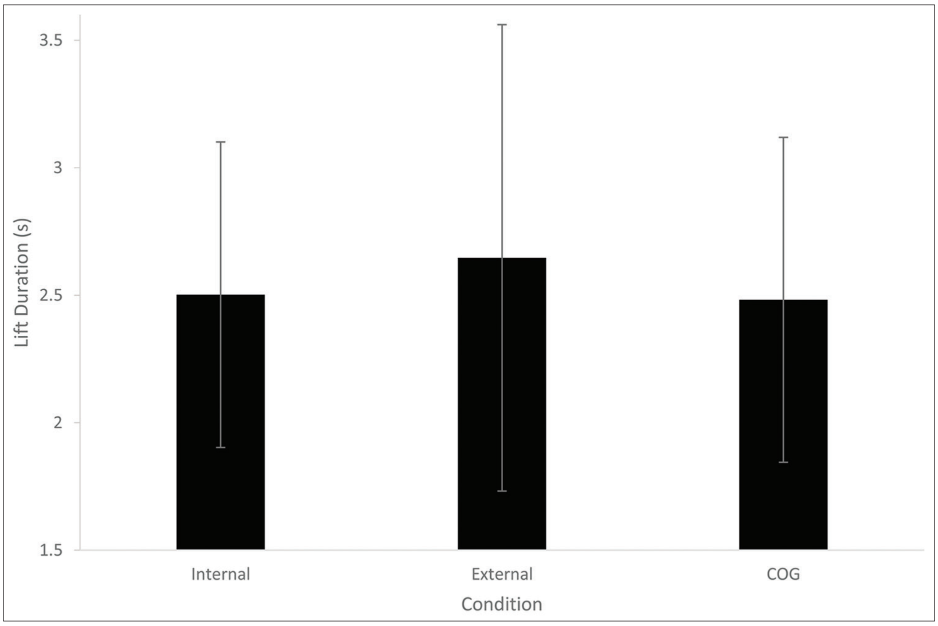


Figure 5. Lift duration as a function of experimental conditions

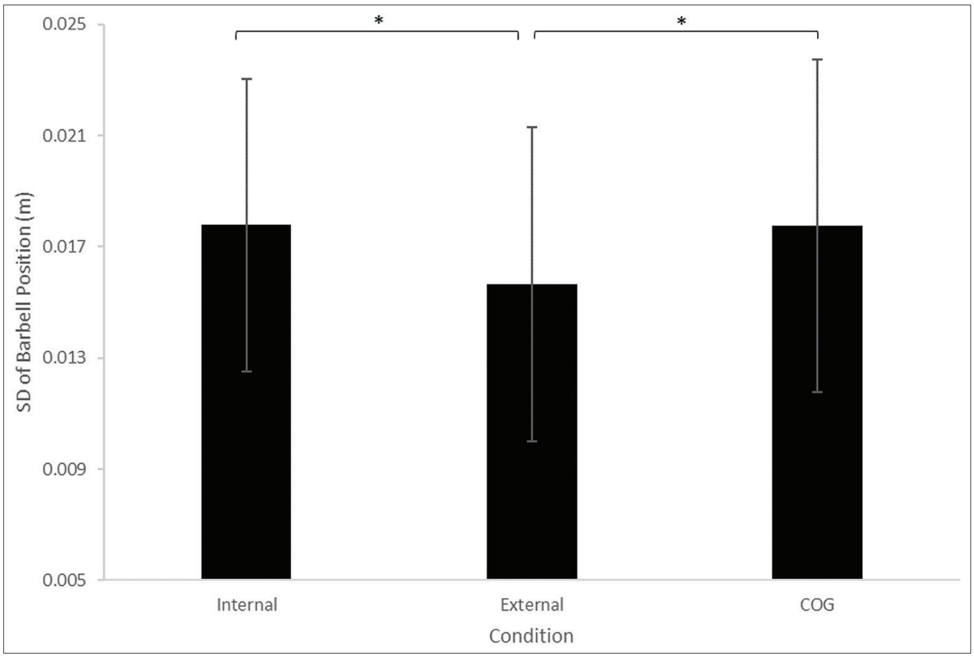


Figure 6. Standard deviation (SD) of the barbell position in the anterior-posterior direction (AP) as a function of experimental conditions. Significant difference between conditions = *

the results of the present work show no significant differences between an EF and an IF for lift duration ($p > 0.05$) and peak barbell velocity in the inferior-superior direction ($p > 0.05$). These findings suggest that attentional focus effects diminish at higher loading intensities, which is congruent with previous studies (Calatayud et al. 2016; Snyder & Fry, 2012) that investigated the effects of IF instructions on muscle activity during multi-joint resistance exercises. Snyder & Fry (2012) and Calatayud et al. (2016)'s findings both indicate a threshold between 60 to 80% of 1RM exists where adopting an IF no longer results in greater muscle activation relative to neutral instructions. However, as indicated by other attentional focus studies pertaining to force production tasks, greater muscle activation does not directly result in greater force production (Marchant, Greig, & Scott, 2009; Wulf, Zachry, Granados, & Dufek, 2007). Rather, Wulf et al. (2007) suggests that a decrease in agonist muscle activity paired with greater force production derived from an EF is the result of a reduction in agonist-antagonist co-activation. Though the present work did not measure muscle activity, pVGRF ($p > 0.05$), peak hip moments ($p > 0.05$) and peak hip powers ($p > 0.05$) indicated no significant differences between any of the conditions which further reinforces the notion that attentional focus effects diminish at high intensity loads.

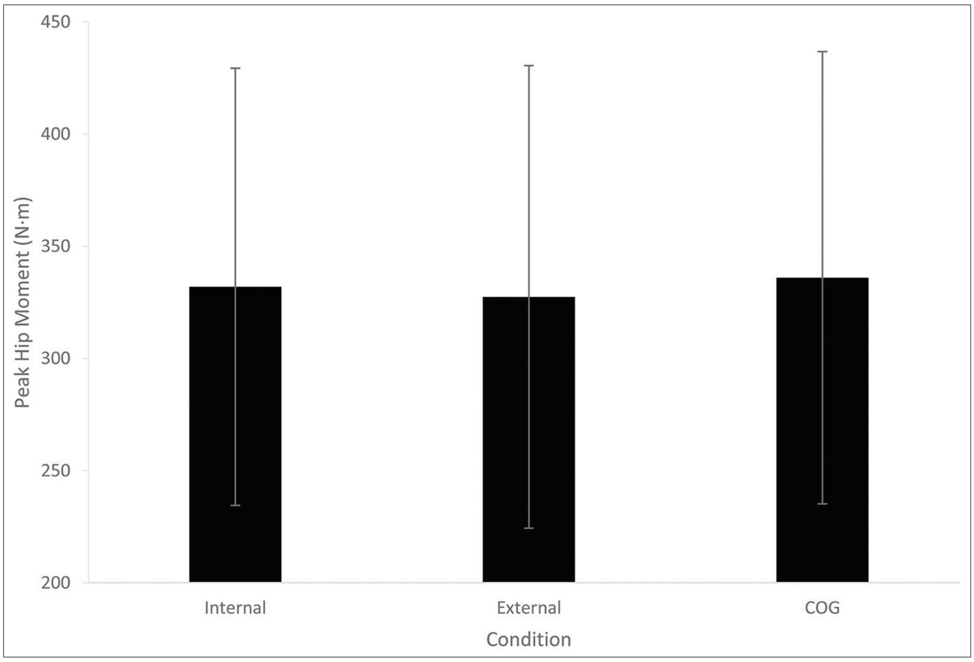


Figure 7. Left peak hip moment means as a function of experimental conditions

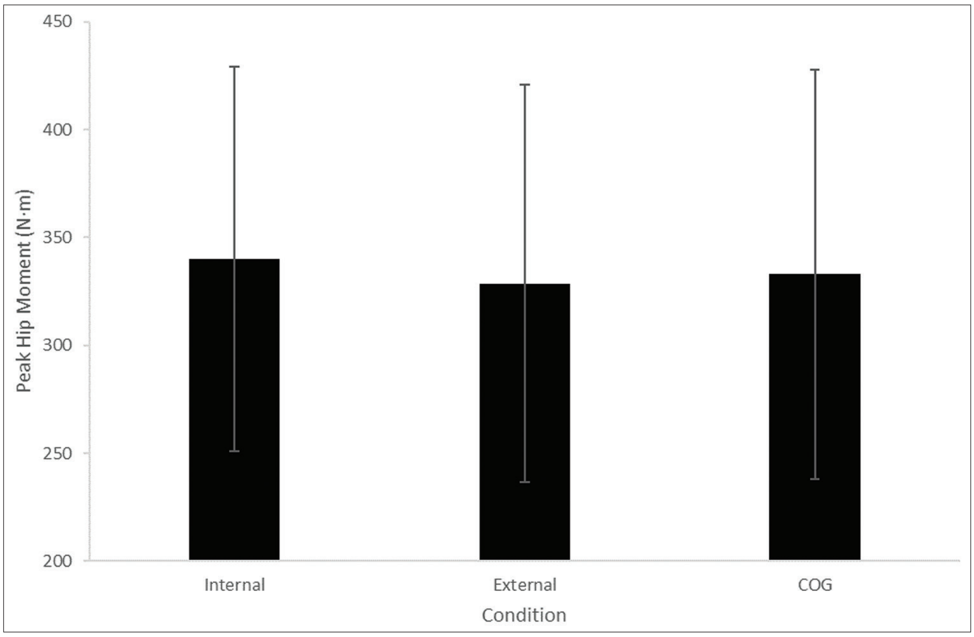


Figure 8. Right peak hip moment means as a function of experimental condition

Contrary to these findings, Wulf & Dufek (2009) reported greater lower extremity joint moments and less EMG activity (Wulf, Dufek, Lozano, & Pettigrew, 2010) when comparing an EF to an IF during vertical jumps. Furthermore, Marchant et al. (2009) reported greater peak net joint torque for an EF relative to an IF during a maximal isokinetic elbow flexion task. Collectively, these studies indicate that there is a profound attentional focus effect at play during tasks that require maximal force production. However, these studies draw large distinct differences from the conventional deadlift (e.g. lack of object manipulation, different force-velocity profiles, the use of a single joint versus multiple joints etc.), which creates difficulty when attempting to compare findings. Nevertheless, a possible reason for the lack of differences between attentional foci for the previously mentioned variables could be from the sheer intensity of the motor task. De Luca & Kline (2012) reported motor unit recruitment thresholds and rate coding vary amongst different muscle groups, which may occur below 100% of maximum isometric voluntary contractions. This would suggest a possible ‘ceiling effect’ may be present in reducing the neuromuscular benefits associated with an EF for maximal force production tasks. More specifically, at high intensity loads, the efficiency of motor unit recruitment and firing are likely already maximized in experienced populations. From an intermuscular perspective, the co-activation of agonist and antagonist muscles acting on the hip are also likely minimized at loads nearing an individual's 1RM, thus maximizing one's efforts in completing the lift.

Attentional Focus Effects on Posture During the Conventional Deadlift

Interestingly, adopting an EF still resulted in less barbell position variability in the AP direction ($p < 0.05$), suggesting a more consistent deadlift performance than adopting the IF or performing the COG. While Lohse et al. (2010) have previously suggested that movement variability can be related to "functional variability", we presume that this may be due to the EF yielding superior postural stability as evidenced by a significantly lower mean velocity ($p < 0.05$) and SD of COP ($p < 0.05$) in the AP direction, along with a trend for less sway amplitude ($p = 0.074$). Though an increase in movement variability may be related to "functional variability" for a dart throwing task, the same rationale should be applied with caution when considering heavily loaded conventional deadlifts. Lohse et al. (2010) noted that an increase in muscle recruitment resulting from an IF may have reduced the degrees of freedom available at the shoulder joint that could have otherwise compensated for changes in other movement parameters during dart throws. This would effectively reduce an individual's ability to use "functional variability" to yield the desired outcome (i.e. the dart landing on the bullseye). As previously mentioned, when performing heavily loaded conventional deadlifts, motor unit recruitment and muscle activation are likely maximized. Similar to the IF condition in Lohse et al. (2010)'s study, this would limit the influence of "functional variability" by restricting the degrees of freedom about each joint. Rather, the reduction in barbell position variability in the AP direction during an EF may be the by-product of greater postural stability derived from greater automaticity. This rationale is more consistent with previous findings made by Polskaia et al. (2014), Richer et al. (2017), and the constrained action hypothesis. According to this hypothesis, consciously attending to one's movements (i.e. IF) may interfere with the automaticity of motor control processes that regulate movement, whereas focusing on movement effects (i.e. EF) may promote the automaticity of said motor control processes (McNevin, Shea, & Wulf, 2003). However, without EMG, Polskaia et al. (2014) were unable to determine if the greater postural stability from the EF was from an increase in automaticity, or if it was due to an ankle stiffening strategy. Richer et al. (2017)'s findings provided evidence (i.e. increase in MPF with no increases in muscle activity about the ankle joint) that the increase in postural stability measures were the result greater automaticity. Drawing from this chain of logic, we rationalize the decrease in barbell position variability in the AP direction is the result of greater automaticity as suggested by the constrained action hypothesis. However, without the addition of EMG data, our rationale remains speculatory.

Dual-tasking Effects on Conventional Deadlift Performance

The findings of the present study revealed the COG yielded similar results to the attentional focus conditions with regards to barbell kinematics and force production. That is, no significant differences were found when comparing the COG with the attentional focus conditions for lift duration, peak barbell velocity in the inferior-superior direction, pVGRF, peak hip moments, and peak hip powers. Given that the same loading intensity was used across all conditions, the same rationale for the lack of difference between attentional focus conditions can be applied here (i.e. near maximal motor unit recruitment and muscle activation may cause a potential 'ceiling effect' that reduces an individual's ability to express the neuromuscular effects of attentional focus). Moreover, the results of the present study suggest that performing the COG yielded a less stable postural performance relative to an EF as evidenced by a greater SD of COP ($p < 0.05$), a greater mean velocity ($p < 0.05$) and a trend for larger sway amplitude ($p = 0.074$) in the AP direction. This is inconsistent with previous postural control studies (Polskaia et al., 2014; Richer et al., 2017) that found greater postural stability to be associated with a COG when compared to an IF or EF. The difference between these studies and the present work may be due to the difference in cognitive demand resulting from the motor task. The limited attentional capacity sharing model for explaining dual-task interference would suggest that a competition for information processing resources would occur between the COG and the motor task (Lorist, Kernell, Meijman, & Zijdewind, 2002). Given that information processing resources are finite, and the summation of information processing demands exceeds the capacity of the individual, the performance of one or both tasks would be compromised (Lorist et al., 2002). More specifically, the information processing demands of performing a COG during quiet standing are likely within one's information processing capacity, whereas performing a heavily loaded conventional deadlift in conjunction with the COG may exceed one's information processing capacity. Since COG trials that exceeded the error count threshold were removed from the data set (i.e. 1 COG trial was removed due to exceeding the error count threshold), only the trials where the participants placed greater information processing capacity on the COG remained. Therefore, the decrease in postural stability when performing the COG and the conventional deadlift simultaneously may be the result of cognitive resource competition between tasks. Alternatively, the bottleneck model suggests that critical tasks are processed sequentially (Lorist et al., 2002) and presents an equally viable rationale for the present findings. During the experimental testing sessions, several participants verbalized that they performed the COG and motor task sequentially. Given the short duration of the motor task and the rate at which the number sequence is presented, participants adopting this strategy would be able to score below the error threshold. Furthermore, the lack of significant differences between the COG and the IF for all the variables in the present study suggests that the participants may have opted for an IF when performing the conventional deadlift during the COG trials. This potential phenomenon would be congruent with previous literature suggesting that athletes primarily adopt an IF and may switch between an IF and an EF during skill execution (Porter, Nolan, Ostrowski, & Wulf, 2010; Porter, Wu, & Partridge, 2010).

Limitations

It is critical to note several limitations that exist within the present study. First, without EMG data about the lower body joints, we are only able to speculate that muscle activation and motor unit recruitment were nearly maximized due to the loading intensity. Including EMG would not only enable the future studies to examine the magnitude of muscle activation, but also the timing of those activations. EMG data about the muscles of the ankle joints (i.e. dorsiflexors and plantar flexors) and the knee joints (i.e. knee extensors and knee flexors) may provide valuable information regarding the differences in postural control between conditions for the present study. Despite the variety of logistical barriers that may prevent the use of EMG (e.g. electrodes on the anterior side of the body inhibiting regular AP barbell trajectory, cost, etc.), future studies examining the effects of any manipulation on heavily loaded conventional deadlifts should consider including EMG. Second, the difficulty of the COG used in the present study erred on the difficult side in the efforts to prevent participants from allocating any attentional resources to the motor task. While with respect to the constrained action hypothesis this would induce greater automaticity, the difficulty seems to have been set too high and may have resulted in a large amount of dual-task interference which ultimately overwhelmed the participants. Future studies comparing attentional focus to a COG should consider scaling the difficulty of the cognitive task such that it does not overwhelm the participant, but still fully engages their attentional resources. Lastly, the present study only included a single set of instructions for each attentional focus type. Given that there are numerous coaching cues that can be used to evoke an IF or an EF, future studies should also include multiple sets of instructions that compare the effects of different coaching cues within the same sub division of attentional focus.

Novel and sport specific recommendations can be made based off the findings of the present work and the current state of the literature. First, athletes performing heavily loaded barbell movements in competition (e.g. powerlifters, strongman, weightlifters etc.) should consider using EF cues to acquire the postural stability benefits when performing heavy repetitions. This is true whether the athlete is attempting to improve the quality of their repetitions in training or trying to maximize their performance in competition. Perhaps the only period when experienced strength athletes should consider using an IF rather than an EF would be when attempting to maximize muscle hypertrophy during the off-season. Schoenfeld et al. (2018) found that using an IF over time yields greater muscle hypertrophy relative to an EF. Given that postural stability demands are likely not the limiting factor in performing resistance exercises at the moderate intensities typically used when training for muscular hypertrophy, adopting an IF would be the superior option. Lastly, until further research is completed on the use of a cognitive task on sport performance, athletes and coaches should avoid using it in their training and competition performances.

CONCLUSION

In summary, the results of the present work indicate that the effects of attentional focus diminish when conventional deadlifts are performed at loading intensities that are close to an individual's one repetition maximum, which is consistent with previous literature attentional focus effects on muscle activation (Calatayud et al., 2016; Snyder & Fry, 2012). This was shown by the lack of significant differences between attentional foci for lift duration, peak barbell velocity and the kinetic measures (i.e. pVGRF, peak hip moments and peak hip powers). Furthermore, performing the COG resulted in no significant differences when compared to the attentional foci for the aforementioned variables suggesting that the intensity of the motor task may be causing a 'ceiling effect'. Moreover, adopting an EF appears to improve the consistency of barbell positioning in the AP direction (i.e. lower SD of barbell position in the AP direction) and improve postural stability (i.e. Smaller SD of COP in the AP direction, slower mean velocity in the AP direction, and a trend for less sway amplitude), which may be due to greater automaticity. Conversely, performing the COG increased variability in barbell positioning in the AP direction and resulted in less postural stability relative to the EF. This was attributed to the large amount of cognitive-motor interference derived from the information processing demand required to perform both tasks simultaneously, exceeding the lifter's processing capabilities. Collectively, these findings suggest that adopting an EF may have limited impact on postural stability when performing heavily loaded barbell exercises typically seen in some strength-based sports.

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