Visual feedback attenuates mean concentric barbell velocity loss, and improves motivation, competitiveness, and perceived workload in male adolescent athletes

ABSTRACT

It is unknown whether instantaneous visual feedback of resistance training outcomes can enhance barbell velocity in younger athletes. Therefore, the purpose of this study was to quantify the effects of visual feedback on mean concentric barbell velocity in the back squat, and to identify changes in motivation, competitiveness, and perceived workload. In a randomised-crossover design (Feedback *vs.* Control) feedback of mean concentric barbell velocity was or was not provided throughout a set of 10 repetitions in the barbell back squat. Magnitude-based inferences were used to assess changes between conditions, with *almost certainly* greater differences in mean concentric velocity between the Feedback (0.70 ±0.04 $m \cdot s^{-1}$) and Control (0.65 ±0.05 $m \cdot s^{-1}$) observed. Additionally, individual repetition mean concentric velocity ranged from *possibly* (repetition number two: 0.79 ±0.04 vs. 0.78 ±0.04 $m \cdot s^{-1}$) to *almost certainly* (repetition number 10: 0.58 ±0.05 vs. 0.49 ±0.05 $m \cdot s^{-1}$) greater when provided feedback, while *almost certain* differences were observed in motivation, competitiveness, and perceived workload, respectively. Providing adolescent male athletes with visual kinematic information while completing resistance training is beneficial for the maintenance of barbell velocity during a training set, potentially enhancing physical performance. Moreover, these improvements were observed alongside increases in motivation, competitiveness and perceived workload providing insight into the underlying mechanisms responsible for the performance gains observed. Given the observed maintenance of barbell velocity during a training set, practitioners can use this technique to manipulate training outcomes during resistance training.

Keywords: Kinematic feedback, back squat, resistance training

INTRODUCTION

Adolescent athletes participating in sport are typically exposed to strength and conditioning programmes (9, 39, 42). In particular, strength and conditioning interventions often incorporate resistance training, which is safe and effective for adolescent athletes (25), and demonstrates favourable developments in muscle size, force, and power (25, 26). Resistance training programmes are developed by manipulating numerous variables (i.e. exercise type, order, intensity, volume of repetitions and sets, allotted rest, and movement velocity), to alter the physiological response and adaptation (7). Given the importance of these variables, substantial research has been placed upon their implementation and outcomes, typically focusing on exercise intensity and volume (7, 11).

More recently, the role of repetition velocity ($m \cdot s^{-1}$) within a resistance training programme has received increased attention (29). This is likely due to advances in portable technology (e.g. linear position transducers) which have the ability to monitor this training variable. Research has demonstrated the importance of barbell velocity for the enhancement of muscular strength and power (29). For example, Pareja-Blanco and colleagues (29) established superior adaptations in lower body strength (effect size (ES): 0.94 vs. 0.54) and power (ES: 0.63 vs. 0.15) when physically active males completed resistance training with maximal intended velocities compared to sub-maximal. As such, strategies to manipulate repetition velocity may be advantageous when prescribing resistance training programmes to improve physical adaptations in adolescent athletes.

It is also acknowledged that athletic development would benefit from a multidisciplinary approach (24), although this is rarely presented within the literature. Previous research (2, 31) has suggested that utilising strategies (e.g. verbal feedback) can enhance motivation and/or competitiveness, consequently improving acute resistance training performance (i.e. velocity, power, force). While these studies provide an insight into the potential benefits of feedback during resistance training, neither study has assessed the psychological responses or the potential changes in perceived mental workload. With the relationship between motivation and competitiveness known to help drive sporting outcomes and adherence (13), it is important that these variables are quantified. Furthermore, it is unknown whether these improvements in kinematic outcomes occur alongside increases in perceived workload (2, 31).

Changes in resistance training performance due to visual kinematic feedback have not been investigated in adolescent athletes. Additionally, while improvements and increases in psychological characteristics have been suggested (i.e. motivation, competitiveness, and workload) (2, 31), these outcomes have not been substantiated. Therefore, the aim of this study was to assess the effects of visual kinematic feedback on mean concentric barbell velocity during the back squat in adolescent athletes. In addition, the effect of kinematic feedback on motivation, competitiveness, and perceived workload was also assessed.

METHODS

Experimental approach to the Problem

To assess the effects of visual feedback on mean concentric velocity, motivation, competitiveness, and perceived global workload during the back squat, 15 sub-elite adolescent rugby players performed the back squat exercise with and without visual kinematic feedback on two separate occasions in a randomised crossover design. Each trial (Feedback and Control) was separated by 7 days. Before and after the exercise, subjects were provided a questionnaire which assessed motivation levels at that moment in time. In addition, after the exercise subjects completed a questionnaire regarding levels of competitiveness and overall perceived workload that they experienced during the task.

Subjects

15 male sub-elite adolescent rugby union players (mean ± SD age; 17.1 ± 0.5 years, height 1.81 ± 0.07 m, body mass 85.1 ± 9.4 kg, three repetition maximum (3RM) back squat 88.8 ± 18.8 kg) from an independent school in the United Kingdom volunteered to participate in this study. Testing took place in February (which is within the second half of the school boy rugby playing calendar). Each subject had regularly used the back squat exercise in resistance training programmes and had at least six months of resistance training experience (41). All subjects were informed of the risks and benefits of this study, and signed a consent document prior to commencement. Experimental procedures were approved by the institutional ethics committee, while assent and parental consent were provided along with permission from the school.

Experimental Procedures

All testing was conducted at the same time of day one week apart, with 72 hours' rest occurring prior to procedures. Subjects were instructed to maintain normal dietary habits in the 24 hours prior to testing, with caffeine not being consumed in the 12 hours before. All subjects completed a baseline session including anthropometric and 3RM back squat strength assessments. Two testing sessions (i.e. Feedback and Control) were then completed in a randomised crossover design with group designation decided by computer-generated random numbering (36). Both sessions consisted of a standardised warm-up and one set of 10 repetitions of the back squat at 65% of 3RM (3). The Feedback condition consisted of participants completing 10 repetitions with an iPad (iPad Pro, Apple Inc., Cupertino, California, USA) directly in front of them at standing eye level. The iPad in the Feedback condition displayed mean concentric barbell velocity upon the completion of each repetition of the back squat. The Control condition consisted of the subjects completing the 10 repetitions without any visual feedback. Mean concentric velocity was assessed via the back squat due to its common use in resistance training programmes (16, 34) and ability to develop lower body strength and power in similar cohorts (42). Questionnaires, which assessed motivation, competitiveness, and perceived workload, were completed 10 minutes before and after the completion of the back squat exercise in both conditions.

Lower-body Strength Assessment

In the week prior to completing the Feedback or Control trials, the 3RM back squat was assessed as previously used in similar cohorts (38, 39). With the bar resting on the upper trapezius, subjects lowered themselves so that the top of their thigh was parallel with the floor. The eccentric portion of the squat was two seconds with a one second pause at the bottom of the exercise. The concentric portion of the exercise was instructed to be as "forceful and powerful" as possible. Instructions were maintained during both the Feedback and Control trials. Upon completion of testing, 65% of each subject's 3RM maximal back squat was calculated.

Experimental Trials

Following a standardised warm up, all subjects completed one set of 10 repetitions of the back squat at 65% of 3RM. All repetitions in both the Feedback and Control trials were required to be completed in the same manner as the lower-body strength assessment with the concentric phase again instructed to be as "forceful and powerful" as possible. Mean concentric velocity ($m \cdot s^{-1}$) was obtained through utilising a GymAware (Kinetic Performance

Technology, Canberra, Australia) optical encoder which sampled at 50-Hz with no data smoothing or filtering. The numerical value of each individual repetition was visually provided to the participant in the Feedback condition at the completion of each repetition. No visual feedback was provided to subjects in the Control condition. No other verbal feedback or communication was provided throughout the set and until the completion of the questionnaires in either condition.

The GymAware consists of a spring-powered retractable cord, with one end of the cord attached to a barbell and the other end attached to a pulley system that is coupled with an optical encoder. The velocity of the barbell is calculated from the spinning of the pulley as the cord extends and retracts, with high levels of validity and reliability (coefficient of variation = <5%) (4, 20). The GymAware provides one pulse approximately every three millimetres of barbell displacement, with the displacement time-stamped with a one millisecond resolution (2, 10).

Assessment of motivation, competitiveness, and perceived workload

Motivation to complete the exercise was assessed using the motivation subscale from the Dundee Stress State Questionnaire (DSSQ) with this subscale previously reporting acceptable reliability ($\alpha = 0.78$) (27). All items were scored on 10-point Likert scales.

Competitiveness was measured using an adapted version of the 4-item competitiveness scale from Anderson and Carnagey (1) which has previously reported acceptable levels of internal reliability ($\alpha = 0.84$).

The National Aeronautics and Space Administration Task Load Index (NASA-TLX) (17) was used to gauge subjective task-related workload during the trial due to its high level of validity and reliability (*r* = 0.94) and ability to objectively evaluate cognitive load during exercise (18, 19). The NASA-TLX is composed of six items that measure mental demand, perceived physical demand, temporal demand, performance, effort, and frustration. The six items were aggregated together to produce an overall 'global workload' score.

Statistical Analyses

Data are presented as mean ± standard deviation (SD). Prior to analysis, all data were log-transformed to reduce bias arising from non-uniformity error, and then analysed for practical significance using magnitude-based inferences (5). The chance of the mean concentric velocity or the psychological characteristic being lower, similar, or greater than the smallest worthwhile change (i.e. 0.2 x between participant difference) was calculated using an online spreadsheet (21). The probability that the magnitude of the change was greater than the smallest worthwhile change was rated as <0.5%, *almost certainly not*; 0.5-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possibly*; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5% *almost certainly*. Differences less than the smallest worthwhile change were described as *trivial*. In cases where the 90% CI crossed the lower and upper boundary of the smallest worthwhile change, the magnitude of the difference was described as *unclear (22)*.

RESULTS

Figure 1 shows the mean concentric velocity for the Feedback and Control conditions across the 10 repetitions of the back squat exercise. The mean (±SD) concentric velocity for all participants for the Feedback condition was 0.70 $m \cdot s^{-1}$ (±0.04), while the mean concentric velocity for the Control condition was 0.65 $m \cdot s^{-1}$ (±0.05). *Almost certainly* greater mean concentric velocity for the Feedback condition was reported, with inferences for each individual repetition ranging from *possibly* to *almost certainly* greater.

Insert Figure 1 here

Pre- and post-motivation, competitiveness, and perceived workload were all found to be *almost certainly* greater in the Feedback protocol (Figure 2). Of the six items which compose the NASA-TLX questionnaire, the Feedback condition reported *almost certainly* greater values on the 10-pt Likert scale in mental demand (7.87 ± 0.92 vs. 6.13 ± 1.30), perceived physical demand (7.13 ± 0.99 vs. 5.40 ± 0.91), temporal demand (7.40 ± 1.45 vs. 6.27 ± 1.16), performance demand (7.47 ± 1.30 vs. 6.07 ± 0.70), and effort (8.07 ± 0.80 vs. 7.33 ± 0.82). The final item in the NASA-TLX scale, frustration, was reported to be *almost certainly* greater in the Control condition (1.60 ± 1.12 vs. 4.60 ± 1.18).

Insert Figure 2 here

DISCUSSION

The purpose of this investigation was to determine the acute effects of visual feedback of mean concentric velocity on back squat performance and psychological outcomes in sub-elite male adolescent athletes. *Almost certainly* greater concentric velocity was observed across the set when visual feedback was provided, with individual repetitions showing *possible* to *almost certainly* greater mean concentric velocity across the 10 repetitions. Furthermore, subjects reported increased motivation, competitiveness and perceived workload when feedback was supplied. These results provide an improved understanding of adolescent performance and the intricate link between psychological factors and physical outcomes.

Providing visual feedback *almost certainly* improved mean concentric velocity of a resistance training set in the barbell back squat exercise in sub-elite adolescent athletes. Additionally, when inferences of individual repetitions are observed across the set it appears that changes become more certain. These findings suggest that providing feedback for male adolescent athletes throughout resistance training sessions could be highly beneficial in improving training session quality, particularly as fatigue develops. While this study is over an acute time-frame (i.e., 1 set), by improving training quality it is postulated that superior training adaptations may occur, as has previously been observed in velocity based training research (31). Furthermore, when placed in context with the relatively small changes in power that professional athletes incur across prolonged training periods (35), improvements of 7.6% in mean set velocity suggests this is a worthwhile finding for the development of adolescent athletes.

The effects of visual feedback were considerably larger than those demonstrated in previous research (2). Argus et al. (2) demonstrated improvements of 1.3% in mean peak concentric velocity in the bench throw exercise when similar kinematic information was verbally provided. It is hypothesised that these differences may be due to the training experience of the participants involved and the resistance training movement (i.e. the back squat rather than the bench throw) utilised. It is commonly accepted that well trained athletes are able to recruit a larger percentage of motor units than their lesser trained counterparts (14, 40). With participants in the current study having only 12-24 months' resistance training experience, previous speculation that feedback improves motor unit recruitment may assist in explaining the larger improvements observed in this younger, relatively inexperienced cohort, who may have more room for improvement of muscle activation (2). Additionally, due to the larger proportion of muscle mass in the lower body compared to the upper body, there may have been an increased scope for greater recruitment to occur (6). Coaches therefore may show preferential application of instantaneous feedback to movements of the full or lower body compared to the upper body, however future research is still required to investigate these mechanisms.

This study also provides the novel aspect of being the first to explore the underlying psychological mechanisms associated with feedback and resistance training performance. Previous research has speculated that improvements in velocity, force, and power in response to instantaneous feedback while resistance training, may be due to improved motivation and competitiveness (2, 31). However, neither these factors or any other psychological factors were assessed in their research (or any other similar research, to the authors' knowledge). This study assessed the impact of instantaneous feedback on motivation, competitiveness, and perceived workload, and found that all three were greater when feedback was provided relative to a no-feedback control. Therefore, it seems reasonable that the improvements in performance were due to improvements in motivation and competitiveness, which were in turn a result of the immediate feedback. Strength and conditioning staff should therefore be aware of the potential impact that immediate feedback can have on the adolescent psychological state and how this may improve physical performance and outcomes.

With the increase in mean set concentric velocity, motivation, and competitiveness however, came an increase in perceived workload. This suggests an increase in cognitive load which may impact upon physical fatigue (28). As stated earlier, global workload was measured by aggregating scores from the six subscales of the NASA-TLX scale (17). We note that participants reported higher scores in the feedback condition for five of the six subscales: perceived physical demand, mental demand, temporal demand, performance, and effort. This is to be expected given the performance improvements that were concurrently observed in the feedback condition. Notably, participants reported considerably lower frustration levels (the remaining subscale) for the feedback condition relative to the control condition. This reduction in frustration may therefore positively influence training outcomes such as adherence and wellbeing. While previous research assessing the implications of feedback on performance have not addressed workload measures (2, 31), it has been shown that adolescent athletes complete greater resistance training volumes and intensities over prolonged periods when external motivating factors are present (8, 34). It is unknown whether this increase in global workload could have an accumulative effect on an athlete (12), however, this should be considered during the planning of resistance training programmes. Furthermore, research is required to assess the impact, if any, of objective instantaneous feedback on total training load over a training cycle.

Finally, it should be stated that the provision of feedback and the corresponding improvement of motivation and competitiveness appears to mitigate the acute effects of fatigue on resistance training across a set (Figure 1). This may assist the athlete who is wishing to not only improve strength or power, but also muscular hypertrophy. It is known that terminal mean velocity of the back squat is ~0.35 $m \cdot s^{-1}$ (15, 23, 32), and that by being able to maintain higher velocities throughout a set, an athlete may be able to complete larger volumes prior to reaching this terminal point. These increased training volumes could potentially lead to improved muscular development (32, 33). Indeed, recent research has suggested that increasing volume through the monitoring of velocity loss in the back squat can induce increased cross sectional area of the quadriceps (30). Therefore, future research should consider investigating whether increased motivation and competition through objective visual feedback could improve resistance training volume and physical characteristic change.

While this study is the first to assess the role of instantaneous feedback on physical and psychological measures, it is not without its limitations that might reduce its application to real life practice. Firstly, due to the current study being across an acute time frame (i.e. a single set), it is unknown whether effects are diminished or augmented with prolonged use of visual feedback. Randell et al. (31) previously demonstrated the beneficial effects of feedback on physical adaptations in adults, however these findings may not be replicated in adolescents. Secondly, the psychological outcomes demonstrated in the current study may have been enlarged due to the novel application of visual feedback. It is feasible that motivation and competitiveness may diminish over time, therefore future research may need to assess not only long term physical adaptations, but also psychological responses. Finally, the current study was completed in sub-elite adolescent male athletes aged between 16-18 years. Because of this selective use of participants, it is unknown whether findings may differ between varying cohorts. Male and female adolescents are known to have differing motivating factors and perceptions towards exercise (37), and it would be imprudent to assume psychological and physical responses are identical across individuals of varying demographics.

In conclusion, this study presents the effects of instantaneous visual feedback in the back squat on mean concentric velocity in sub-elite male adolescent athletes. Furthermore, this study has been the first to investigate the psychological mechanisms associated with improved performance outcomes from feedback in this context. The findings demonstrate that visual feedback throughout a set of the back squat can promote *almost certain* improvements in mean concentric velocity in sub-elite male adolescent athletes. Additionally, it was established that motivation and competitiveness are closely associated with these improvements, and it is possible that these psychological factors are responsible for the improvement in performance through instantaneous feedback. This feedback appears to also increase perceived workload however, which is something that should be noted when considering longer-term use of feedback in this context. This study suggests that instantaneous objective feedback should be utilised when completing resistance training to increase motivation and competitiveness and improve performance. However, future research is required to assess how these improvements in velocity affect cumulative training load and adaptation.

PRACTICAL APPLICATIONS

Based on the current findings, providing augmented feedback through knowledge of performance to male adolescent athletes improves motivation and competitiveness which manifests in improved training quality. Therefore, it is suggested that visual feedback of kinematic outcomes is supplied when training quality is of importance (e.g. during periods of power development). Alternatively, the practitioner may choose to provide visual feedback during resistance training sessions that require high training volumes. This feedback may mitigate the effects of fatigue on mean concentric barbell velocity as a set progresses. Moreover, by providing kinematic feedback, the practitioner may have a smaller time commitment supervising and generating motivation within athletes. Finally, the practitioner can also utilise feedback during periods of low athlete motivation. Provision of feedback can enhance motivation and improve effort when completing resistance training.

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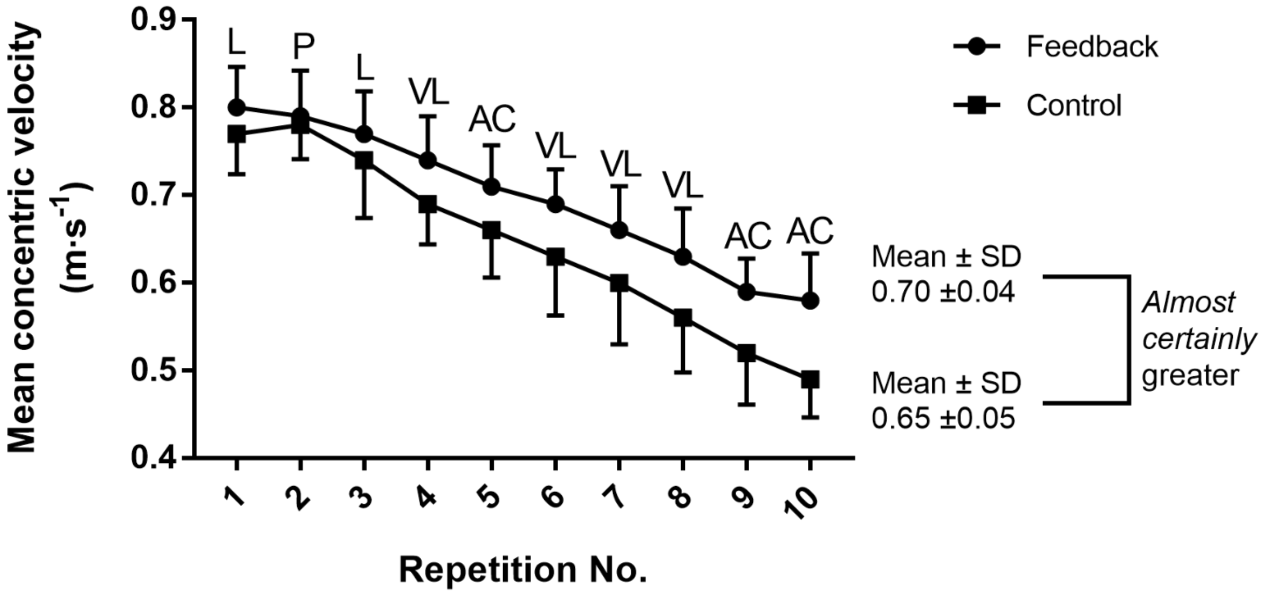
Figure 1. Mean concentric barbell velocity and inferences of individual repetitions across a single set of the back squat in the Feedback and Control conditions. L = *likely*, P = *possibly*, VL = *very likely*, AC = *almost* certain.

Figure 2. Mean ±SD scores and inference of pre- and post-motivation, competitiveness, and perceived workload within respective 10-point Likert scales. AC = a*lmost certain* differences.

Figure



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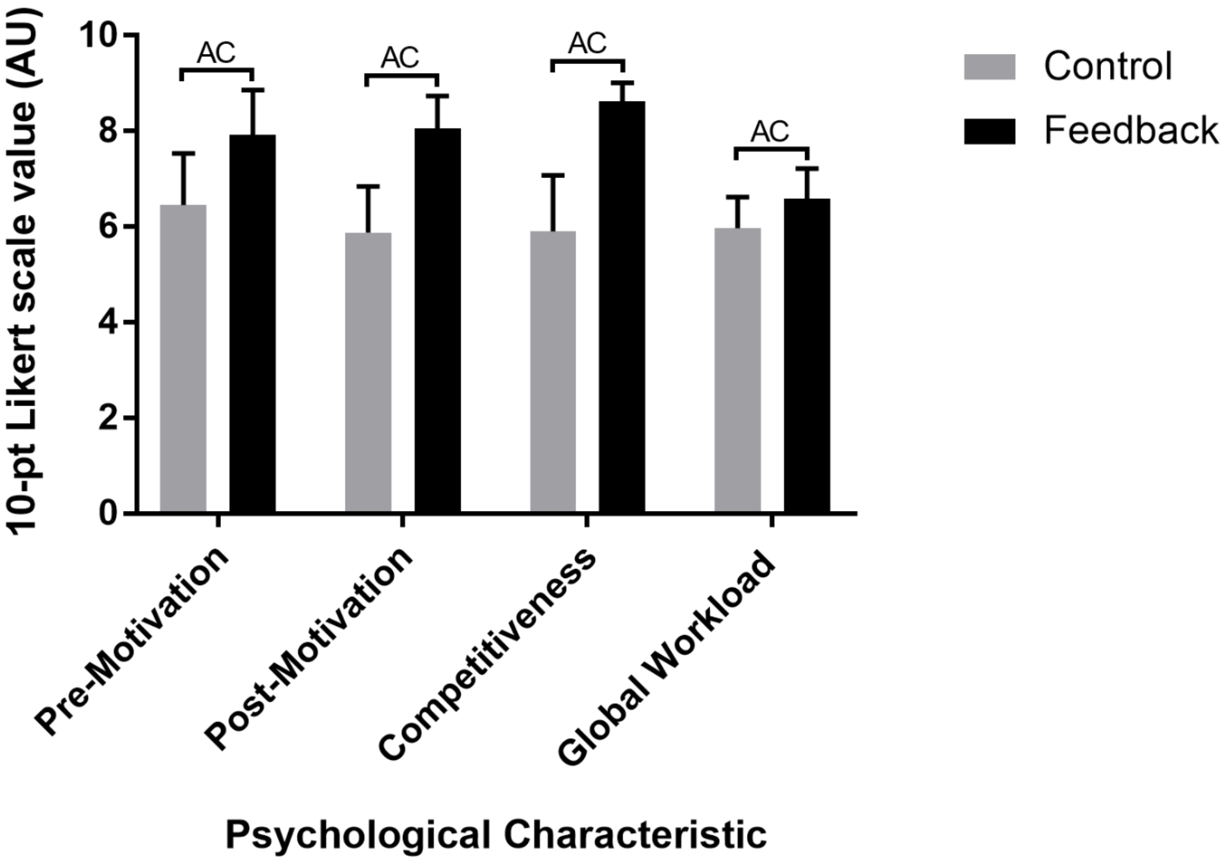

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