European Journal of Human Movement

OPEN ACCESS

Original Research

Effects of head position on back squat power performance

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Received: 01/03/2021; Accepted: 27/04/2021; Published: 31/06/2021

Abstract: The effect of head positioning is often not accounted for when optimising performance in the back squat exercise. The primary aim of the study was to identify the most advantageous head position for peak power (PP), peak velocity (PV) and peak force (PF) performance in the back squat exercise. A secondary aim was to identify the most favourable head position. Twenty male rugby union players performed 1x3 repetitions at 75% one repetition maximum (1RM) to determine their preferred pre-intervention head position, followed by 1x3 at 75% 1RM in a flexed (FP), extended (EP) and neutral (NP) neck position, performed in a counterbalanced and randomised order. PP, PV, PF and comfort level (CL) were measured during each repetition. FP resulted in significantly higher PP (3147.50 ± 464.70 W; $p<0.05$) compared to EP (2730 ± 427.83 W) and NP (2912.95 ± 441.16 W). However, NP resulted in significantly greater CL than FP and EP (3.65 ± 0.59; $p<0.05$). Therefore, when performing the back squat at 75% 1RM, the FP can be adopted to optimise power performance if there is no pain and no detriment to movement kinematics.

Keywords: back squat, head position, kinetics, rugby union

1. Introduction

The back squat is used for developing lower body strength and power. Therefore, to best develop these physical characteristics, the technical model should facilitate lower body power production through a high force and velocity output (Zink, Perry, Robertson, Roach, & Signorile, 2006). Development of peak power (PP), peak velocity (PV) and peak force (PF) in the lower body positively correlate with improvements in squat performance (Adams, O'Shea, O'Shea, & Climstein, 1992; McBride, Triplett-McBride, Davie, & Newton, 2002). Additionally, PP, PV and PF's development correlates to improved sprint and jumping performance (Hermassi, Chelly, Tabka, Sherpard, & Chamari, 2011), highlighting the importance of using the most technically advantageous squat technical model for maximising force, velocity and power production.

The back squat exercise involves triple flexion and extension of the hip, knee and ankle and is used to develop physical characteristics related to sprint and jump performance (McBride, Blow, Kirby, Haines, Dayne, & Triplett, 2009; Adams, O'Shea, O'Shea, & Climstein, 1992; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). Squatting is also used as a movement and injury screening tool for lower extremity injury risk (Case, Knudson & Downey, 2020; Comfort & Kasim, 2007). According to Comfort, McMahon, & Suchomel (2018), the correct execution of the deep back squat exercise requires a neutral foot position approximately shoulder-width apart, anterior movement of the knees, an upright torso and a forward and upward gaze (Comfort, McMahon & Suchomel, 2018). However, there is a lack of research to support these guidelines. Research on the squat technical model divides the technique into five main areas: ankle mobility, knee stability, hip mobility, and the trunk and head position (Kritz, Cronin, & Hume, 2009). Strength and conditioning coaches should understand the technical model and movement patterns of the exercises they coach to reduce injury risk and apply the most advantageous technique to elicit adaptation.

In the back squat, the spine is placed under axial loading (Orloff, Veil, & Askins, 1997). Excessive lumbar flexion or extension increase sheer and compression stresses that may result in lower back injury and reduced performance (Walsh, Quinlan, Stapleton, FitzPatrick, & McCormack, 2007; Schoenfield, 2010). The cervical spine has been shown to impact the pelvis via coordinated alignment of the two segments (Scheer *et al*., 2013). The pelvis has also been shown to contribute to lordosis of the lumbar spine, presenting a link between the pelvic alignment and lower spinal control (Jackson, Phipps, Hales, & Surber, 2003; Nelson, Walmsley & Stevenson, 1995). Research has also shown there to be relationship between head positioning and cervical alignment (Wang, Deng, Li, Wang, & Zhan, 2017). Therefore, there is a link between the cervical spine and lumbar lordosis, suggesting that head position and cervical alignment can impact the posterior chain by altering the alignment of both the pelvis and lumbar spine. This presented link may affects the posterior chain's integrity by aligning key segments. According to Schoenfield (2010), the lumbar spine's natural lordotic curve should be maintained during back squatting, as excessive flexion or extension may increase the risk of injury and reduce performance (Schoenfield, 2010).

Although spinal alignment and head positioning during back squatting appear to be critical, there is limited research on the effects of head positioning on back squat performance. Previous work suggests that athletes should maintain a neutral, forward head position to limit trunk extension (Donnelly, Berg, & Fiske, 2006). Donnelly, Berg & Friske (2006) examined the effect of gaze direction on squat kinematics and concluded that the head position and direction of gaze should not be allowed to drop below neutral. However, this study examined the impact of gaze and not head positioning. As head and eye movements can be independent of one another, the role of head positioning remains unclear (Donnelly, Berg, & Fiske, 2006; Kritz, Cronin, & Hume, 2009; Myer *et al*., 2014; Schoenfield, 2010). Moreover, despite previous head positioning recommendations in proposed back squat technical models (Donnelly, Berg, & Fiske, 2006; Kritz, Cronin, & Hume, 2009; Myer *et al*., 2014; Schoenfield, 2010), the effects of head positioning on power performance are unknown. Therefore, the current study examined the effect of head position on PP, PV and PF performance during the back squat exercise. A secondary aim was to determine the most comfortable head position as self-selected by Rugby union players.

2. Materials and Methods

Subjects — Twenty male collegiate rugby players (mean±SD: age, 19.95±1.10 yrs; body mass, 97.67±12.12 kg; height, 181±4.91 cm) volunteered to participate in the study. Participants were randomly selected from the Cardiff Metropolitan University Rugby Football Club from a pool of athletes receiving 4-5 strength and conditioning sessions per week at Cardiff Metropolitan University. Participants were required to have a minimum of one year of strength training and back squat training experience. All participants were informed of the study requirements, benefits and potential risks and completed a Physical Activity Readiness Questionnaire (PAR-Q) to avoid any contraindications to exercise. The participants provided written informed consent, and the Cardiff Metropolitan University Ethics Committee granted ethical approval to the study.

Experimental Design — The one-repetition maximum (1RM) for the back squat exercise was acquired from assessments taken within four weeks of testing to quantify the experimental sessions' load.

Methodology —All 1RM testing was completed as part of university S&C testing, which was conducted by two UKSCA accredited S&C coaches. Squat racks (Hammer Strength Equipment, Falmouth, Kentucky) and a 20kg Olympic bar (Eleiko, Sweden) with calibrated 2-inch weight disc plates (York, United Kingdom) were set up facing a wall with both the ceiling and floor visible when the participant stood in the set-up position, 150 cm away from the wall. For each individual, a tape marker was placed on the wall at three different positions. To create a 15° upward head angle (neck extended position; EP), the marker was placed at a point 40 cm above eye level (Figure 1). To create a downward 45° head angle (neck flexed position; FP), the marker was placed 150 cm lower than the eye level (Figure 2). Finally, for a neutral neck position (NP), the marker was placed at eye level (Figure 3). Based on each individual's eye level, the markers' placement allowed for standardised head positioning, excluding stature as a variable.

Each squat repetition's depth was standardised by reaching a depth determined by a medicine ball and a plate holder. The medicine ball's superior surface was 38 cm above the ground to ensure that all participants squatted to a position where the hip axis was lower than the knee axis on the horizontal plane. Before the assessment, each participant was asked to perform three repetitions at 75% of 1RM with no control for head positioning to determine self-selected head positioning. The participants then performed in a randomised and counterbalanced order 1x3 repetitions at 75%1RM at each of the three head positions, with 5 min rest allowed between each set for a full recovery (De Salles, Simao, Miranda, da Silva Novaes, Lemos, & Willardson, 2009). Participants were instructed during each set to maintain their head position directly in line with the tape markers placed on the wall. When participants moved their head during a repetition or failed to reach the required depth, the data were omitted from further analysis.

Measures of PP, PV and PF were assessed at each repetition using a linear position transducer (GymAware Power; Kinetic Performance Technologies, Canberra, Australia – for validity and reliability see O'Donnell, Tavares, McMaster, Chambers, & Driller, 2018), with the highest measures used for further analyses. Finally, after each set, a Likert scale was used to rate each head position's comfort level (CL), but not load and exertion perception. All participants where familiarised with the rating scale (table 1.) prior to testing.

Table 1. Likert Scale to assess comfort of head position during back squat

Likert Scale of Comfort				
Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable
1	2	3	4	5

Statistical Analysis — Means and SD for all three conditions were calculated using Microsoft Excel (Microsoft Corporation, Microsoft Campus, Reading, UK). The normality of the data was examined using the Shapiro-Wilk test and normal distribution was confirmed. Significant differences in PP, PF, PV and CL between the three different neck positions (EP, FP and NP) were examined using a repeated measure analysis of variance (ANOVA). Pairwise comparisons with Bonferroni adjustment were used for posthoc analysis. Assessment of effect size via partial eta and power from the ANOVA were also calculated. The statistical significance level was set at $p<0.05$. A Statistical Package for the Social Sciences (SPSS Version 26.0, SPSS, Inc., Chicago, IL, USA) was used for all analyses.

Figure 1. Extended head position (EP) at both the top and bottom position of the back squat exercise.

Figure 2. Flexed head position (FP) at both the top and bottom position of the back squat exercise.

Figure 3. Neutral head position (NP) at both the top and the bottom position of the back squat exercise.

3. Results

Anthropometric characteristics and baseline 1RM squat data are presented in Table 2. The participants' head position preference during 1 x 3at 75% 1RM with no instruction was neutral as 19 out of the 20 participants maintained their head in a neutral neck position.

Table 2. Anthropometrics and Baseline 1RM squat data (Means ± SD) for participants [n=20]

	Mean	± SD	Max	Min
Age (Yrs)	19.95	1.10	22	18
Body mass (kg)	97.67	12.12	120	75
Height (cm)	181.07	4.91	188	175
1RM (kg)	171.88	21.05	200	140

Peak Power- The repeated measures ANOVA revealed a significant difference between EP, FP and NP for PP (p = 0.05; partial eta = 0.514, power = 1.00). PP was significantly higher for FP compared to EP (t (19) = 7.11, p = 0.0001), FP was significantly greater than NP (t (19) = 3.93, p = 0.001), and NP was significantly greater than EP (t (19) = 2.34, p= 0.001; see Figure 4).

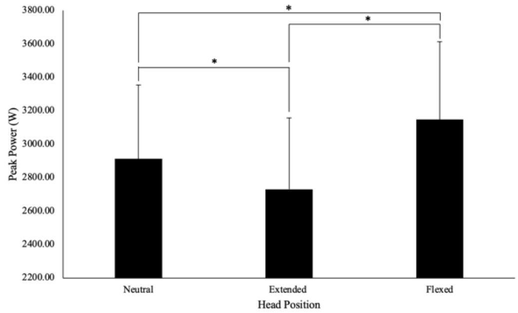

Figure 4. Mean ± SD for peak power (W) for neutral, extended and flexed head positions. * denotes a statistically significant difference (p<0.05) between head positions.

Peak velocity- The repeated measures ANOVA showed a significance between EP, FP and NP for PV (p = 0.05; partial eta = 0.389, power = 0.992). A significant difference for PV was found between the FP and EP (t (18) = 5.73, p = 0.0001); and between NP and EP (t (18) = 2.71, p= .01). However, there was no significant difference (p>0.05) present between FP and NP (t (19) = 1.72, p = 0.10) (see Figure 5).

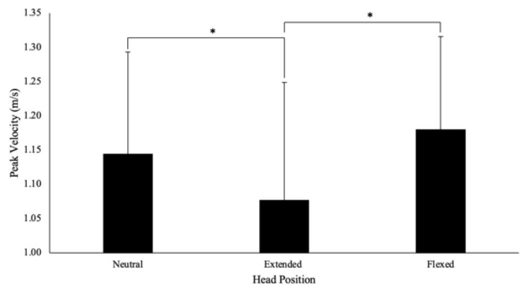

Figure 5. Mean ± SD for peak velocity (ms^{-1}) for neutral, extended and flexed head positions. * denotes a statistically significant difference (p<0.05) between head positions.

Peak Force- The repeated measures ANOVA revealed a significant difference between the three conditions (p = 0.05; partial eta = 0.835, power = 0.523). Peak force for FP was significantly greater compared to both EP (t (19) = 2.952, p = 0.008) and NP (t (19) = 2.800, p = 0.011). However, there was no significant difference between NP and EP (t (19) =0.104, p= 0.919; see Figure 6).

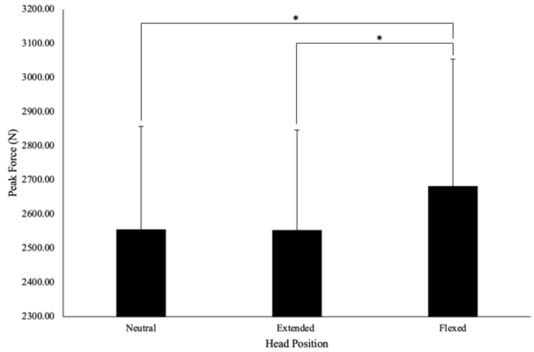

Figure 6. Mean ± SD for peak force (N) for neutral, extended and flexed head positions. * denotes a statistically significant difference ($p<0.05$) between head positions.

Comfort Level- The repeated measures ANOVA showed a significance for the Likert scale between the three conditions ($p = 0.05$, partial eta = 0.432, power = 0.998). There was a significant difference for CL between the NP and the EP ($t(19) = 6.43$, $p = 0.0001$), and FP ($t(19) = 2.69$, $p= 0.01$), and between FP and EP ($t(19) = 2.34$, $p = .03$; see Figure 7).

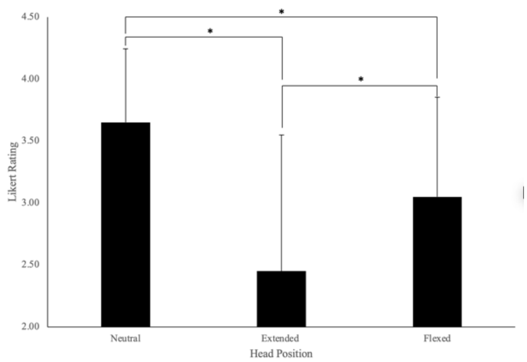

Figure 7. Mean ± SD for Likert rating for neutral, extended and flexed head positions. * denotes a statistically significant difference ($p<0.05$) between each of the three head positions.

4. Discussion

The study examined which head position provides the highest power performance and comfort during the back squat exercise, performed at 75% 1RM. We found that FP (a downward head angle of 45 degrees) resulted in significantly greater PP, PV and PF than EP and significantly greater PP and PF than NP. The NP position also resulted in significantly greater PP and PV than EP. CL assessment showed NP as significantly more comfortable compared to the FP and EP. Therefore, according to the current findings, FP is the most advantageous position for maximising PP, PV and PF, while the EP resulted in the lowest performance outcomes. However, NP was the most favourable position for comfort level.

According to the current findings, FP resulted in greater power during the back squat exercise by allowing greater force and velocity. In particular, it appears that FP is more advantageous for force generation compared to the other two head positions. Therefore, placing the head into the FP could potentially allow for greater loading in the back squat exercise and could allow for greater strength gains that may positively impact other sporting characteristics. For example, increased strength is positively correlated to sprint speed, jumping, throwing and tackling in Rugby Union (Baker, & Nance, 1999; Kraska, *et al.*, 2009; Lachowetz, Evon, & Pastiglione, 1998; Speranza, Gabbet, Johnston, & Sheppard, 2015). These relationships highlight how altering an athletes' head position during squatting, which can increase lower body triple flexion and extension strength, may help develop such characteristics. A significant difference was only present between the FP and NP for PV against the EP. PV in the FP and NP was 0.1ms^{-1} and 0.06ms^{-1} greater, respectively, than the EP, suggesting that an athlete should avoid extending their head past NP during the back squat. As there was a significant difference between FP and NP in PP and not in PV, the head position has a greater impact on force than velocity, confirmed by the significantly higher PF observed in FP compared to EP and NP.

The higher power production seen with FP may be due to the head position allowing the posterior chain to be in neutral alignment at the back squat's lowest position. In Figure 3, at the lowest point of the back squat, the cervical spine is placed into excessive extension, which creates a kink in the posterior kinetic chain, which may subsequently alter the alignment of the lumbar spine and pelvis and reduce posterior tension (Black, McClure, & Polansky, 1996; Scheer *et al.*, 2013). Extension can also be seen in Figure 1, which is further exaggerated at the bottom of the squat, positioning the posterior chain into a weakened, unaligned position, which may be detrimental to performance and safe, effective movement. In contrast, FP enables a more natural head position for the rest of the spine at the bottom of the movement (see Figure 2), creating better alignment and greater tension in the posterior chain. This increase in the ability to generate tension may have resulted in significantly higher PP. The specific adaptation that an athlete aims to achieve should be considered when discussing these findings. If an athlete aims to maximise their force production, the head should be placed in an FP during squatting. However, if an athlete aims to develop movement velocity, extending the head above the NP should be avoided as both the FP and NP showed significantly greater PV than the EP.

Our findings contradict previous work that concluded athletes should be cautioned against allowing their gaze direction to drop below neutral due to increased trunk and hip flexion (Donnelly, Berg, & Fiske, 2006). However, Donnelly et al. (2006) investigated the effect of gaze direction on kinematic variables and not kinetics. Donnelly (2006) also concluded that although there is a relationship between gaze direction and head position, it is not perfect, and recommended that S&C professionals be aware of this lack of relationship when coaching the back squat (Donnelly, Berg, & Fiske, 2006). This lack of relationship may explain the discrepancy between his findings and ours. Donnelly's (2006) conclusions, using only 10 participants, should be viewed cautiously due to the small sample and effect size.

Myers *et al.* (2014*)* stated that common culprits for excessive trunk flexion are weakness in the thoracic spine, inability to maintain scapular depression and retraction, and lack of thoracolumbar fascia tension, yet does not mention the role of head position. Therefore, the relationship between gaze direction and trunk flexion may not be as crucial as other anatomical factors that impact trunk flexion. If an athlete fails to maintain a trunk angle parallel to that of the tibia, and excessive flexion is evident, the coach should alter the technique to limit the amount of flexion (Myers *et al., 2014)*. Initial alterations should focus on developing strength and increasing tension in the posterior kinetic chain, increasing thoracic mobility and strength and developing proprioceptive awareness of the scapular. If these alterations fail to correct the error, movement of the head position, or gaze direction, upwards and away from the downwards position should be seen as an appropriate alteration to technique, and any sacrifice to performance from the subsequent alteration should be seen as a means to aid in reducing injury risk. However, an athlete who can show competency and efficiency in all back squat positions can apply the current study's findings to generate greater force and velocity by altering the head position. However, if this alteration of head position negatively impacts movement kinematics, the athlete should return their head to the NP. The head position selected at the start of the movement (set position) should be maintained throughout the entire squat movement to avoid movement pattern alteration, affecting muscle activation and limb and joint coordination (Myer *et al.*, 2014). The combination of the present study and Donnelly's (2006) findings should inform S&C coaches on head position effects on performance and injury in the back squat.

A significant difference was found between each of the three head positions in the CL through a Likert scale, with the NP showing the greatest CL, in contrast to PP, PV and PF, where the FP was the most effective position. The Likert scale was used due to its simplicity and easy understanding during the limited rest between conditions (Bertram, 2007). Thus, the Likert scale was deemed appropriate to use despite limitations previously reported for reliability of this subjective rating scale. During testing, each condition was implemented using a randomised and counterbalanced order to eliminate bias and fatigue onset, both of which may have affected CL in each condition. The difference between PP, PV and PF compared to the CL results may be explained by the preferred head position reported in Table 2. Nineteen out of the 20 participants naturally selected NP during a 75% 1RM squat, with no intervention from the researchers, explaining the increased CL for NP since participants were mostly familiar with the NP head position. As the participants were exposed to the FP and EP for only a single set and on the day of the assessment only, there is a need for future CL assessment across prolonged use of these head positions. Although altering an athlete's head position decreased CL in the squat in this study, the finding should be viewed cautiously due to the Likert scale's subjective nature. Therefore, the focus should be on the role of continued practice in optimising technique. Future research should examine whether this decrease in CL is reduced when alternative head positions are used for an extended period rather than once. A longitudinal study would allow CL to be examined over an extended period to assess if CL is related to familiarity with each head position during back squatting. Due to the subjective nature of the current study's rating, each athlete should assess their CL during the back squat in each of these positions. However, it is recommended that, unless painful or deemed very uncomfortable, the FP should be used when performing a back squat due to its performance benefits.

The squat is one of the most used exercises in S&C, with different styles used for different reasons (Jones, Smith, Macneughton, & French, 2016). However, there are differences between these variations, e.g. in the kinetics and kinematics of the traditional back squat, powerlifting squat and the box squat (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012), and in the kinematics and electromyographic activity of the back and front squat (Yavuz, Erdağ, Amca, & Aritan, 2015). Therefore, future research should examine the effect of head position on performance during these different squatting styles. Furthermore, since this study examined male Rugby Union players only, the findings cannot be generalised to female athletes; indeed, females use different movement strategies than males (Graci, Van Dillen, & Salsich, 2012). Finally, we only examined effects at 75% of 1RM, limiting the study's application to different intensities. Future research should examine the interaction between different intensities and head positions on squat performance, as a wide range of intensities is used in S&C to acquire adaptations.

5. Practical Application

Athletes, who possess a high level of technical competency in the back squat, should adopt the FP, with a downward angle of 45 degrees, to generate more PP, PF, and PV when performing a back squat at 75% 1RM. The athlete should only adopt this position in the absence of pain or discomfort. However, if pain or discomfort is present, the athlete should maintain a NP.

Acknowledgments: Non-declare

Conflicts of Interest: The authors declare no conflict of interest

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