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Research article

The Effects of Cervical Muscle Fatigue on Balance – A Study with Elite Amateur Rugby League Players

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Abstract
Neck muscle fatigue has been shown to alter an individual's balance in a similar way to that reported in subjects suffering from neck pain or subjects that have suffered a neck injury. The main purpose of the present study was to quantify the effects of neck fatigue on neck muscle electromyography (EMG) activity, balance, perceived fatigue and perceived stability. Forty four elite amateur rugby league players resisted with their neck muscles approximately 35% maximum voluntary isometric contraction (MVIC) force for 15 minutes in eight different directions. Sway velocity and surface electromyography were measured. Questionnaires were used to record perceived effort and stability. Repeated measures ANOVA showed that after 15 minutes isometric contraction, significant changes were seen in sway velocity, perceived sway and EMG median frequency. There were no differences in perceived efforts. The changes in sway velocity and median frequency were more pronounced after extension and right and left posterior oblique contractions but there was no significant difference in sway velocity after contraction in the right lateral flexion, right anterior oblique and left anterior oblique direction of contraction. All the subjects showed oriented whole-body leaning in the plane of the contraction. The experiment produced significantly altered and perceived altered balance in this group of physically fit individuals. The results may contribute to our understanding of normal functional capacities of athletes and will provide a basis for further investigation in healthy non-athletes and participants that have suffered neck injuries. This may ultimately help develop accurate and valid rehabilitation outcome measures.

Key words: Biomechanics, posturography, neck pain, EMG, sports.

Introduction

Neck injuries account for a significant portion of accidents and compensation in the general population. The incidence of such injuries is coincidently quite high in both rugby league and rugby union players. It has been reported that in rugby union, the majority of injuries appear to be the result of buckling of the cervical spine (Kuster et al., 2012). Unfortunately, very little is known about the exact mechanism of injury and the resultant functional disturbances experienced by players (King et al., 2011). Even though our understanding of the relationship between neck injury, neck pain and muscle fatigue is improving, clinically practical methods of assessment disability due to injuries to the cervical spine are few in number (MacDermid et al., 2009; Humphreys, 2008).

Researchers have reported long lasting altered balance due to cervical extensor muscle fatigue (Duclos et al., 2004; Gosselin et al., 2004; Schieppati et al., 2003; Stapley et al., 2006) or after participants were subjected to cervical mechanical stress (Field et al., 2008; Gosselin and Blouin, 2000). Duclos (2004) showed the effects to be present after 30 seconds of either lateral flexion or posterior oblique isometric contraction. No information to date is available on the postural effects of neck flexion or anterior oblique isometric contraction.

The main cause of altered balance following neck muscle isometric contraction appears to be proprioceptive conflicts and possibly central fatigue which in turn increases the sway velocity during quiet stance (Gandevia, 2001; Gosselin et al., 2004). Afferences from small sized muscles have been shown to be modified by central fatigue (Pettorossi et al., 1999). The density of muscle spindles is higher in the small intrinsic, deep dorsal and suboccipital cervical muscles than in other cervical muscle groups which accounts for their important role in proprioception (Djupsjobacka et al., 1995; Peck et al., 1984; Rix and Bagust, 2001) therefore suggested that fatigue of suboccipital muscles could alter balance due to the activation of tonic gamma motor neurons in response to a build-up of muscle contraction metabolites. The consequence of such an accumulation (of K^+, arachidonic and lactic acids) is the promotion of group III and IV afferent signals, leading to positive feedback and further excitation of muscle spindles and gamma motor system hyperactivity (Knutson, 2000; Thunberg et al., 2001). At this point it is unknown if altered function of other cervical muscle groups will influence balance.

Surface electromyography (SEMG) has been used extensively to study muscle fatigue. If muscle contractions are maintained over a certain period, the SEMG power density spectrum shifts towards the lower frequencies, with the change in SEMG being proportional to the build-up of H^+ in the muscle as metabolites are produced and broken down (Oddsson et al., 1997). The median frequency, as measured by SEMG during muscle contraction, is therefore a good indicator of muscle fatigue as it is directly proportional to the build-up of muscle metabolites during a prolonged voluntary muscle contraction (Beck et al., 2013; González-Izal et al., 2010; Merletti et al., 1992; Solomonow et al., 1990).

Increased postural sway is a common symptom of neck trauma as seen in rugby injuries and it is generally attributed to injury involving peripheral and/ or central components of the cervical somatosensory and/or vestibular system (Loudon et al., 1997; Madeleine et al., 2004; Treleaven et al., 2005). Although computerized static posturography is widely used to measure balance impair-

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ments, its main limitation is its high intrinsic inter-individual variability (Di Berardino et al., 2009). Investigators have attempted to decrease what is considered unacceptable static posturography variation by introducing either dynamic disturbances during quiet stance (Cyr et al., 1988; Koozekanani et al., 1980) or by changing the subject's position into a more unstable stance. Unfortunately the high costs of computerized dynamic posturography systems places this type of assessment out of the reach of most clinicians. Investigators have thus turned to measuring quiet stance with subjects standing on foam pads which is thought to amplify postural sway by decreasing the reliability of somatosensory information from cutaneous mechanoreceptors on the plantar surface (Di Berardino et al., 2009).

The purpose of the present study was thus to measure the effect of sustained isometric cervical muscle contraction in eight different directions on balance and perceived stability.

Methods

Forty four (n = 44) healthy male players from the National Conference League premiership (age = 24 ± 2 years; weight = 91± 5.5kg, height = 1.84 ± 0.03m) volunteered for inclusion in this cross-over design study. Exclusion criteria applied included cervical trauma, neck or lower limb pain and visual disturbances during the last three months. Ethical approval was obtained from University's Ethics Committee, and all participants read the information sheet and signed a consent form. Participants were randomized into two equal groups of 22 individuals according to their surnames.

Cervical isometric contraction

Neck muscle fatigue was induced through isometric contractions (Schieppati et al., 2003, Gosselin et al., 2004). Participants were asked to stand comfortably on a predetermined target, with the feet touching each other on a force platform with their arms to their side and leaning slightly towards a support pad. This was provided to help stabilize body movement during the experiment, and was part of a custom built supporting structure (Figure 1). A head weight training harness was placed on the participant's head, from which a cable extended horizontally (standardized between participants) and was attached via a pulley system to an adjustable mass. No significant contraction of the thoracic or lumbar muscle chain below the level of the support was assumed required in order to maintain a steady stance. A marker was attached to the pulley and the experimenter observed if the pulley remained co-planar with a reference point fixed to the supporting structure. During the isometric contraction, the experimenter would give a verbal cue in order for the participant to either increase or decrease the cervical muscle force against the weight thereby maintaining a static head/neck position during 15 minutes. Eight different effort orientations were used each at 45° offset from the previous one (Figure 1). In order to decrease bias due to a participant's tiredness, the experiment was conducted over two days. On day one group 1 was tested in four randomized orthogonal positions (viz. E, F, RLF & LLF). On day two the remaining effort orientations were tested (viz. RPO, LPO, LAO & RAO). The order was reversed for Group 2.

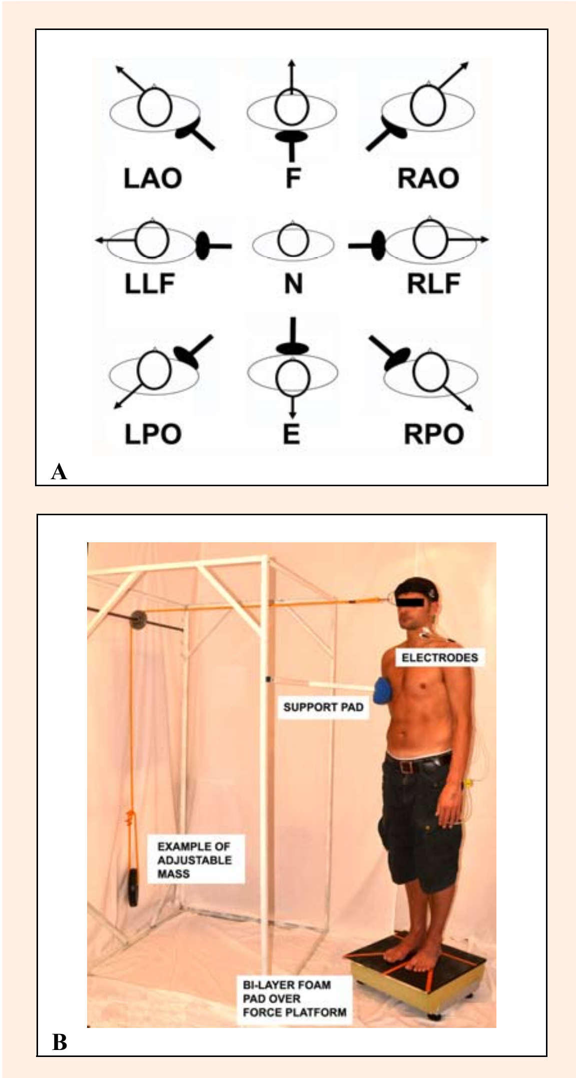

Figure 1. A. The orientation of efforts and neutral position (N). extension (E), right posterior oblique (RPO), right lateral flexion (RLF), right anterior oblique (RAO), left posterior oblique (LPO), left lateral flexion (LLF), left anterior oblique (LAO) and flexion (F). B. Experimental setup showing the subject performing an isometric contraction resisting the adjustable mass in the left posterior oblique direction (LPO). The subject is standing on a force platform covered by a bi-layer foam pad. The effort is produced against a cable placed over a pulley to an adjustable mass. The surface electrodes can be seen over the left shoulder and neck

The load set on the cable was approximated to 35% of the maximum isometric voluntary contraction (Table 1), and was calculated individually for each participant by adapting the isokinetic neck strength profile of elite rugby players data (Olivier and Du Toit, 2008). The isokinetic values were less than other reported valued but permitted us nonetheless to standardize the loads used (Geary et al., 2013). Neck length was measured from the spinous process of the vertebral prominence (C7) to the occipital notch

Table 1. Example of the average masses in kilograms used in each subject for a particular movement.

Direction	E	RPO	RLF	RAO	LPO	LLF	LAO	F
Average torque (Nm) *	56.2	59.5	59.7	50.5	59.5	58.9	50.5	38.9
Peak mass (kg)	54	57.2	57.4	48.6	57.2	56.6	48.6	37.4
35% Peak mass (kg)	18.9	20.0	20.1	17.0	20.0	19.8	17.0	13.0

The mass was obtained by dividing peak torque adapted by from Oliver and Du Toit (2008) by each subject's neck length. The mean neck length was 10.6cm. This peak force was divided once more by the gravitational constant to obtain the load used in kilograms. * Presented by Olivier and Du Toit, 2008)

at the base of the skull, while the head was held in the Frankfort plane (Olivier and Du Toit, 2008).

Due to the absence of normative data for the oblique contractions, we averaged the torque from either the extension and lateral flexion or the lateral flexion and flexion. For example, the RPO load was determined by averaging the E and RLF torques.

Electromyography

Surface electromyography was used to assess changes in muscles involved in isometric contraction. A two-channel EMG system was used to record the SEMG signal during the isometric contraction (iWorks system Model 214, Dover, USA). Standard settings were selected for the assessment, with the low pass filter set to 500Hz, the high pass filter to 10Hz, and the gain to 500 with the common mode rejection ratio set to 110dB. The inter-electrodes distance was 2 cm. Due to the difficulty in accessing specific muscles with surface electrodes, the electrode placement was location-specific rather than muscle-specific (Strimpakos et al., 2005). Electrode placements for the different directions of contraction are presented in Table 2.

The leads were linked to the skin and connected to the iWorks unit. Sampling started 15 seconds after the onset of the muscle contraction and lasted for 4.096 seconds at a rate of 2 KHz and once more after 14 minutes of isometric contraction. The real time wave form was displayed through LabScribe V2.0 software (iWorks, Dover, USA). The raw EMG was processed by performing a linear magnitude fast Fourier transform (FFT) followed by an integration and normalization of the spectrum (values from 0 to 1 volt), with normalization achieved through division by the maximum recorded value. The median frequency of the EMG spectrum was then identified at a value of 0.5. Where SEMG was recorded from two muscles, the median frequencies were averaged to produce one single result.

Posturography

Postural sway velocity and center of pressure displacement (COP) were recorded with the use of a force platform (QPS-200, Midot Med. Technology) linked via a USB connector to a laptop computer and the signal processed with Posture Analyser software (Posture Midot Medical Technology). Postural sway velocity and COP displacement plots provided by the Posture Analyser software were saved in separate files on a computer. One 10cm x 50cm x 50cm bi-layer foam pad was placed on the force platform, where the modulus of elasticity of the foam was measured to be 399N/m^2 (Gosselin, 2011). Participants were asked to stand on the foam pad, feet touching each other with their eyes closed and without their body touching the apparatus' padded vertical support. Sampling was recorded for 30 seconds (Prosperini et al., 2013) at 30Hz per channel on two occasions: 1) One minute before the isometric contraction was started, 2) 15 seconds after the end of the isometric contraction.

Subjective exertion perception

Participants were asked to rate their perceived fatigue/exertion using the Rating of Perceived Exertion (RPE) Borg CR-10 scale. The Borg CR-10 scale consists of a vertical scale labeled 0 to 10 with corresponding verbal expressions of progressively increasing sensation intensity (Borg, 1990).

Subjective postural stability perception

Participants were asked to rate their perceived postural stability by using the same stability scale as used by Schieppati (Schieppati et al., 2003). Scores ranged from 10 (I feel really still, as if supporting myself using a stable frame) to 0 (unable to stand without falling) (Schieppati et al., 1999, Schieppati et al., 2003).

Procedure

The EMG electrodes were applied. The participants stood in a relaxed position with their eyes closed on the foam pad with their body approximately 2 cm away from the support apparatus' padded vertical support. Posturography was measured for 30 seconds. The head weight training strap was adjusted to the head and the appropriate weight

Table 2. Surface EMG electrode placement and potential contribution of each muscle to different actions produced. (based on the method of Strimpakos et al., 2005).

Muscle group	Electrode placements	Action associated with muscles	Reference electrode
Splenius capitis (SC)	Over the muscle belly at C2/3 level between the uppermost parts of trapezius and sternocleidomastoid	RPO, RLF, RAO, LPO, LLF, LAO	C7 spinous process
Sternocleidomastoid (SCM)	Over the muscle belly, about 1/3 of the length rostral to the sternal attachment	RLF, RAO, LLF, LAO, F	Acromion
Cervical paraspinal group (CPG); trapezius, capitis and cervicis groups)	2 cm from the midline at C4 level	E, RPO, LPO,	T1 spinous process

Table 3. Paired samples tests of SEMG median frequency of the cervical muscles recorded showing mean and their standard error mean, lower and upper 95% confidence interval of the difference, t statistic (degree of freedom: 43) and significance.

Direction	Mean (Hz)	SE means (Hz)	t	95 %CI	p
E	35.5	.43	43	34.6 – 36.4	.001
RPO	33.3	.39	84.5	32.6 – 34.1	.001
RLF	60.7	.55	111.3	59.6 – 61.8	.001
RAO	60.1	.49	122.8	59.1 – 61.1	.001
LPO	32.8	.32	103.6	32.1 – 33.4	.001
LLF	28.1	.25	112.9	27.6 – 28.6	.001
LAO	27.7	.19	142.4	27.3 – 28.1	.001
F	27.6	.17	159.2	26.9 – 27.6	.001

Bonferroni correction for eight situations set significance at less than 0.0018.

was placed at the end of the cable. During the neck extension muscle sequence, the participants were instructed to lean forward sufficiently for their chest to touch the padded vertical support and thus maintain the position of the head and neck, and to readjust the position should the experimenter give them a verbal cue. SEMG signals were recorded both from the onset of the contraction and again during the last minute of contraction. These instructions were repeated for to the seven other positions. During the first minute of contraction, participants were shown a Borg CR-10 chart and were asked to select a number on the chart that corresponded to their perceived effort. The contraction was maintained for 15 minutes (Gosselin et al., 2004), during the 14^{th} minute, participants were again shown the Borg CR-10 chart and asked to rate their perceived fatigue.

Once 15 minutes of isometric contraction were completed, the head weight training straps were immediately removed and the participant was asked to hold a comfortable standing position with their eyes closed without touching the support pad. The distance away from the support pad was not standardized. Posturography was again measured for 30 seconds. Participants were then asked to rate their subjective feelings of stability. Participants were allowed 15 minutes recuperation between experimental situations. Overall, the experimentation of the four situations lasted between 2.25 to 2.50 hours.

Statistical analyses

Statistical analyses were performed using SPSS 17.0. The data was tested for normality using the Shapiro-Wilk test. Paired t-tests measured the differences in myoelectic activity and sway velocity between the beginning and end of the isometric contraction. One-way repeated measures analysis of variance (ANOVA) with Greenhouse-Geisser corrections were used to compare myoelectric activity differences and postural sway velocity differences in all eight situations. Paired t-tests compared differences in sway velocity changes after 15 minutes of isometric contraction, RPE (Borg CR-10) and Scheppati scores for each situation individually. Levels of significance were set at 0.05. Bonferroni correction post-hoc test was performed for all t-tests and ANOVAs.

Results

The Shapiro-Wilk normality tests for EMG frequency and sway velocity suggested that normality was a reasonable assumption.

Surface electromyography

Paired t-tests with Bonferroni correction showed that the SEMG median frequency of the cervical muscles recorded during the 1st and 15th minutes of isometric contraction were significantly different in all eight situations (Table 3).

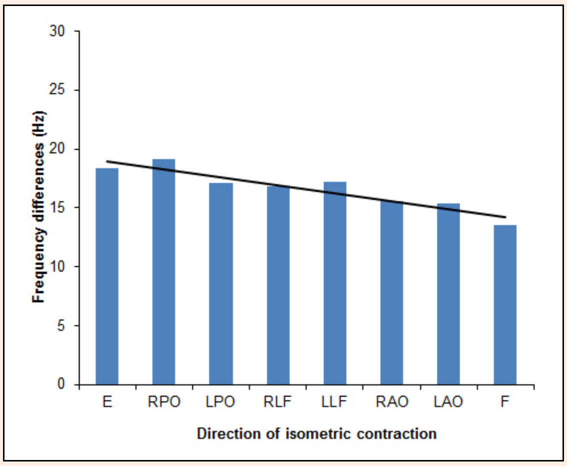

Figure 2. Mean EMG frequency differences (Hz) and standard deviations and linear trend line between initial recording during the first minute of contraction and after 14 minutes in 8 different direction of isometric contraction.

Figure 2 shows changes in median frequency between the first and the last minute of contraction, with the trend line showing that smaller changes were recorded from the anteriorly contracting muscles. A one-way repeated measures ANOVA with Greenhouse-Geisser corrections confirmed that different directions of the 15 minute isometric contractions produced significant changes in the 'before' and 'after' differences SEMG median frequency ($F(4.196, 180.436) = 136.377$, partial $\eta^2 = 0.760$, $p < 0.001$). Post hoc tests using the Bonferroni correction revealed that changes in SEMG frequency during E were significantly different to all other contractions ($p < 0.001$). There were no significant changes in before and after differences in median frequencies between the RPO, RLF and LLF. Nor were there any differences between F, LAO and RAO.

Posturography

Descriptive statistics showed the postural sway velocity to be the largest in isometric contractions involving neck extensor muscles. Changes in velocity were the least affected by the isometric contraction during F, LAO and RAO (Figure 3).

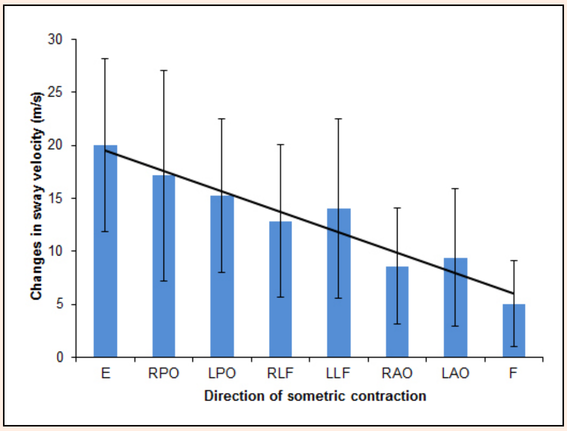

Figure 3. **Mean differences in sway velocity and standard deviations and linear trend line after 14 minutes in 8 different direction of isometric contraction.**

Paired t-tests with Bonferroni correction showed that the postural sway velocity recorded after the 15 minutes isometric contraction produced a significant increase in velocity in E, RPO, and LPO (Table 4).

A one-way repeated measures ANOVA with Greenhouse-Geisser correction showed that significant differences were present between the different effort orientations for postural sway velocity changes ($F(5.77, 248.103) = 25.599$, partial $\eta^2 = 0.373$, $p < 0.001$). Post hoc tests using the Bonferroni correction revealed that postural sway velocity changes were present predominantly in the sagittal plane of contraction. Mirror contractions in the transverse plane did not show significant differences in sway velocity. LPO vs. RPO, LLF vs. RLF, and LAO vs. RAO where all insignificant, whilst all other interactions were significantly different ($p < 0.01$).

Centre of Pressure (COP)

After 15 minutes of muscle contraction, all the participants showed oriented whole-body leaning in the plane of the contraction, which lasted so long that the participant had to compensate repeatedly for this disequilibrium. Figure 4 shows observed COP in neutral position compared to the observed COP motor post-effects that are oriented in the same plane of contraction. Nevertheless, the spatial characteristics of the postural post-effects varied according to the cervical muscle group previously contracted. While postural post-effects were oriented in one direction, the positive or negative value differed in each participant. For example, all participants increased COP displacement in the sagittal plane after contraction, but as seen in previous studies, half of the participants moved forward and half moved backwards. This was observed again in this study, but to a lesser extent during lateral and anterior oblique contractions.

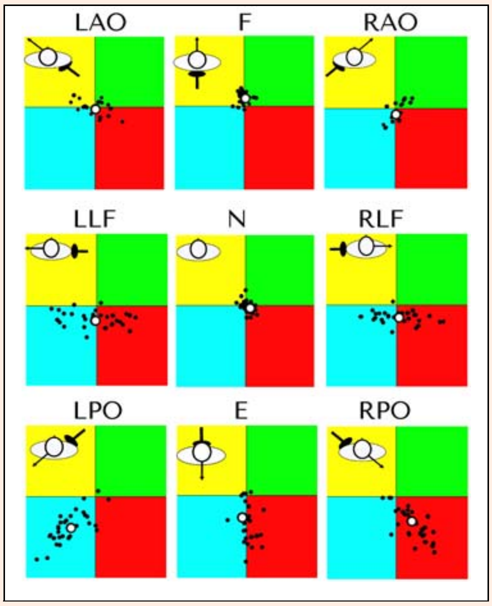

Figure 4. **Centre of pressure (COP) motor post-effects (leaning) are seen oriented in the same direction of contraction after 15 minutes isometric contraction. Extension (E), right posterior oblique (RPO), right lateral flexion (RLF), right anterior oblique (RAO), left posterior oblique (LPO), left lateral flexion (LLF), left anterior oblique (LAO), and flexion (F). White circle represents average change in COP.**

Subjective perception of effort and balance

A one-way repeated measures ANOVA with Greenhouse-Geisser corrections showed that participants' perception of stability was changed after 15 minutes neck muscle isometric contractions in different directions ($F(1.155, 49.564) = 274.03$, $p < 0.001$; Wilks $\lambda = 0.011$, partial $\eta^2 = 0.989$). Post hoc tests using the Bonferroni correction showed that the participants' perceived decrease in stability after isometric contraction occurred mostly during

Table 4. **Paired samples tests of postural sway velocity showing mean and their standard error mean, lower and upper 95% confidence interval of the difference, t statistic (degree of freedom: 43) and significance.**

Direction	Mean (mm/s)	SE mean (mm/s)	t	95 %CI	p
E	10.2	1.6	6.3	6.9 – 13.5	.001
RPO	7.4	1.9	3.9	3.5 – 11.1	.001
RLF	3.1	1.6	1.9	.1 – 6.2	.058
RAO	-1.2	1.4	.842	-4.0 – 1.65	.404
LPO	5.5	1.5	3.6	2.4 – 8.5	.001
LLF	4.3	1.8	2.4	.7 – 7.8	.061
LAO	-.39	1.4	.268	-3.3 – 2.5	.790
F	-4.7	1.0	-4.6	-6.8 - -2.7	.001

Bonferroni correction for eight situations set significance at less than 0.0018.

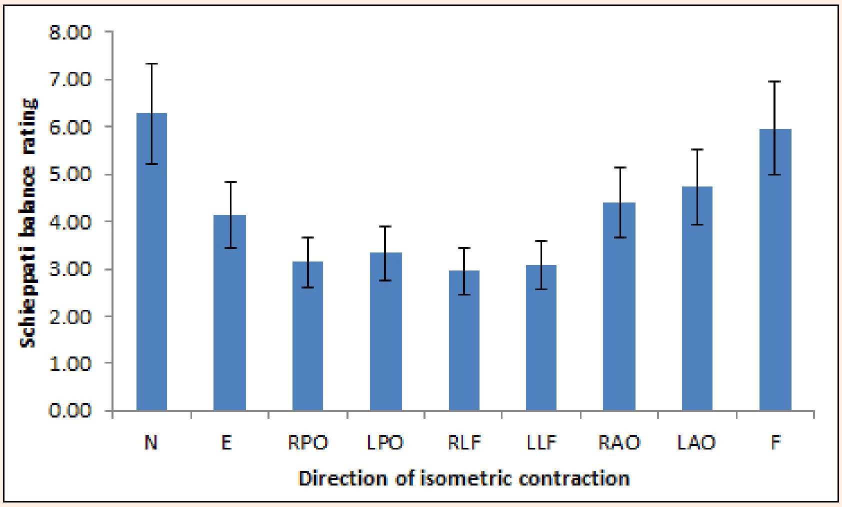

Figure 5. Pre and post isometric contraction perceived sway. The perceived sway and standard deviation between normal stance feet together/eyes closed (N) and after 15 minutes isometric contractions in eight different positions. Feeling of decreased stability is represented by a lower score.

contractions involving some lateral movement (Figure 5). Perception of effort (RPE) on the other hand was not significantly different between directions of contraction (Figure 6).

Discussion

The results of the present study showed that 15 minutes isometric contraction of various neck muscle groups at approximately 35% MVIC produced a significant change in the EMG median frequency in all positions and changed significantly the sway velocity in all directions except F, RLF, RAO, LLF and LAO.

Muscle fatigue

Fatigue development protocols in previous studies have either asked participants to resist loads of 25% or less MVIC from 5 to 15 min, to 35% MVIC for 5 minutes (Gosselin et al., 2004; Edmondston et al., 2011; Schieppati et al., 2003; Stapley et al., 2006,). However, a preliminary study showed that this level of activity was not sufficient to produce significant fatigue or a significant change in the EMG median frequencies in the present participants. It was assumed that this was due to the increased neck muscle strength found in healthy and fit elite amateur rugby league players compared to healthy non-athlete males (Gage et al., 2004; Hogrel et al., 2007). We therefore adapted our protocol by raising the isometric contraction resisted load to 35% of MVIC as used by Stapley et al. (2006) and Schieppati et al. (1999) and extending the contraction period to 15 minutes. Our results confirm that this increased resistance torque produced the required signs of muscle fatigue as manifested by the significant EMG median frequency shift to lower frequencies over the course of the contraction. This shift was more prominent in muscles producing posterior movements such as E, RPO and LPO, which is interesting in view of the fact that all muscles contracted for the same

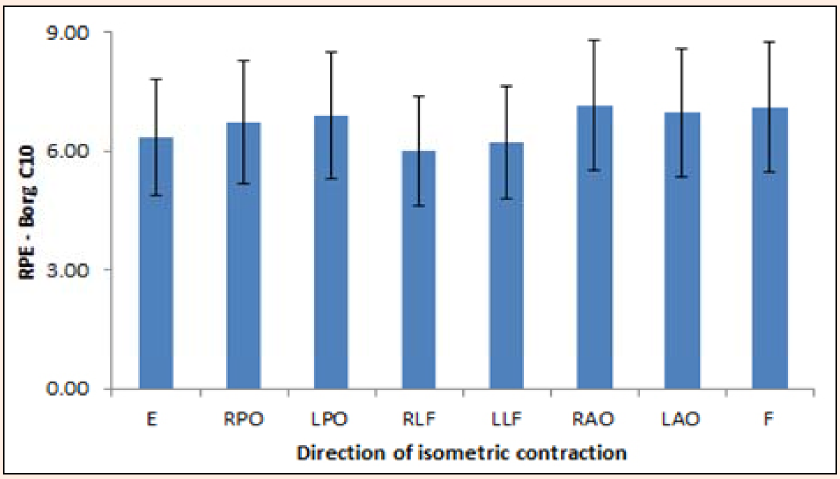

Figure 6. Pre and post isometric contraction perceived exertion. The perceived exertion and standard deviation after 15 minutes isometric contractions in eight difference positions. Feeling of more intense effort is represented by a higher score.

amount of time and at the same percentage of MVIC. This observation is unlikely to be explained our population of highly trained athletes. This could be explained by the difference in proprioceptive receptors in extensor and flexor muscles. The extensor muscles have a higher density, different distribution and morphology of muscle spindles in posterior sub-occipital muscle such as the superior oblique capitis, inferior oblique capitis and rectus capitis posterior major and minor sub-occipital muscles (Kulkarni et al., 2001). These muscles contain up to 100 times more muscle spindles than a muscle such as the trapezius which is one of the main cervical extensor muscle and this may explain their susceptibility to fatigue and hence their greater post-effect loss of proprioceptive function when fatigued (Boyd-Clark et al., 2002).

Postural sway velocity

Mean postural sway velocity appears to be the parameter which shows the least variability and provided the most reliable estimate of COP displacement (Hadian et al., 2008; Lin et al., 2008). COP displacement was therefore selected as the balance parameter for this study.

As shown in previous studies, fatigue of postural muscles such as cervical, lumbar and lower limb extensor muscles reduces the efficiency of postural mechanisms to a greater extent than non-postural muscles (Lin et al., 2009). In our study, postural sway velocity increased after neck extensor muscle contraction which confirms that contraction duration and resistance were set correctly. In addition, the data presented in Figure 3 shows a clear trend. Larger changes in postural sway velocity were observed when posterior muscle groups were fatigued (E; RPO; LPO). Whereas smaller changes in postural sway velocity were observed when anterior muscles were fatigued (F; RAO; LAO). These patterns of sway velocity changes correspond to changes in EMG frequencies. Martin (2006) has shown that in upper arms during fatigue inputs from group III and IV muscle afferents from homonymous or antagonist muscles depress extensor motoneurons where as motoneurons innervating flexors are facilitated (Martin et al., 2006). It is presently unknown if these findings can are applicable to neck muscles. It is possible that neck muscle fatigue or other flexor muscle groups co-activating during the muscle contraction could have affected the sway velocity, as repetitive contraction during a fatigue protocol have been shown to alter postural characteristics (Choi, 2003; Tarantola et al., 1997). This could have produced a Type 1 error. Furthermore, changes in postural parameters sometimes occur after changes in the participants' position therefore any changes in the COP could may have indirectly induced altered velocities (Schieppati et al., 1994). However this was unlikely to occur in our study as the participants' feet and distance from the support pad were controlled for in all conditions.

Posturography also provided information on the participants' COP post-effect displacement in the plane of contraction. "Postural post-effects" are increased body leaning associated to a change in postural reference resulting from a proprioceptive inflow as seen after fatiguing neck muscles. An increase in postural post-effect displacement, mainly in the sagittal plane, has been reported during short duration contraction of postural muscles (Duclos et al., 2004). In a further study, Duclos supported the hypothesis that the change in the postural reference was caused by the erroneous proprioceptive message produced by a sustained voluntary muscle contraction (Duclos et al., 2009). On the other hand Duclos' method differed significantly as he reported on the post-effects of just 30 second contractions and the fatigue protocol had participants sitting instead of standing. . It has also been suggested that the effects observed in this study could be due to changes in the internal representation of the upper body following signs of muscle fatigue (Takahashi et al., 2006).

Perceived effort and perceived postural sway

There were variations between the ratings of perceived exertion although the differences were not significant. We attribute this situation to the methodology used whereby loads were calculated as a percentage of the respective muscle's MVIC. Absence of change in perceived effort has also been reported in a study on military helicopter flight crews (Harrison et al., 2009). Pilots were asked to perform 70% MVIC efforts for a maximum of 180 seconds in flexion, extension and right and left lateral flexion. No statistically significant differences were found between RPE for the four isometric contraction trials ($p = 0.81$). The lack of change in perceived effort is unusual in non-elite athletes as there is a wide variation in perceived subjective muscle fatigue in the general population (Dedering et al., 1999; Troiano et al., 2008; Veldhuizen et al., 2003). This finding could be explained by our sample of participants who were highly trained elite athletes, including three that had played previously in the Super League as professionals. Furthermore, the Borg CR-10 scale results showed that after 15 minutes contraction the perceived effort was scored at less than seven for nearly all participants which indicated that the effort produced, although perceived as difficult, was relatively well tolerated by most. Nonetheless, increased perceived postural sway was more pronounced after posterior and laterally oriented isometric contractions than after contraction of the anterior group of muscles. This perceived instability corresponded correlated with sway velocity measurements but did not correlate with perceived effort or changes in EMG frequency. If we assume that central factors controlling muscle contraction are equal for the various muscle groups used in this study, differences in postural stability and EMG signal must be attributed to local muscular mechanisms.

Rugby union neck injury incidence occur mostly in the scrum, tackle and rucks and mauls and can be nearly 10 per 1000 player hours for mixed populations although there is still a scarcity of severity and analytical data (Swain et al., 2011). Rugby league incidence of neck and spinal injuries is different as most of the injuries occur during tackle and occur in 2.9 per 100,000 players (King et al., 2011). The long-term significance of these injuries can be seen in many of these players who may show evidence of early degenerative changes from as early as 21 years of age (Castinel et al., 2010). In addition to structural changes, players can also show persistent functional disturbance such as altered eye movement control, kinaesthetic sensibility or other symptoms of postural control such as altered balance or the perception of the visual vertical and horizontal (Humphreys, 2008; Treleaven, 2008).

Conclusion

Fifteen minutes of constant neck muscle 35% MVIC in eight different directions in the standing position produced significant altered and perceived altered balance in elite amateur rugby league players. The median frequency EMG and sway velocity were most affected during posteriorly oriented contractions.

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Key points

- Using a percentage of MVIC permits to proportionally fatigue various neck muscle groups evenly
- Fatigue of different neck muscle groups will alter balance differently
- Fatigue of muscles producing extension and posterior oblique will alter balance the most although subjects perceive a greater altered balance after lateral flexion

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