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Associatons between Self-Reported Wellbeing and Neuromuscular Performance During a Professional Rugby Union Season

Running head: Fatigue monitoring in professional rugby union.

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Abstract

Self-reported wellness is often used to monitor fatigue responses to training and competition. Constraints within team sports mean short-form wellness questionnaires are typically preferred to literature-validated documents. This research aimed to assess the relationship between self-reported wellness and neuromuscular performance during a professional rugby union season, and to identify changes in these parameters over a 12-week period. On the first training day each week, prior to activity, 37 players rated 5 wellness subscales ('fatigue/vigour', 'upper-body soreness', 'lower-body soreness', 'mood', 'sleep quality/duration'), on a 1-5 Likert scale (1 representing the lowest wellness), and 5-repetition countermovement jumps (CMJ) were completed following a warm-up. Each week, total wellness, wellness subscales, and 4 CMJ measures for each participant were calculated as change from baseline. Within participant correlations were determined between changes in wellness and CMJ measures, whilst week-to week differences and differences from baseline were assessed using Wilcoxen Signed-Rank tests. Within-participant correlations were compared for players grouped by age, and position. Wellness and CMJ scores fluctuated according to physical stress, persisted beneath baseline throughout, and showed declining trends over 12-weeks. Very large (r = 0.7-0.89)/large (r = 0.5-0.69) correlations were identified between wellness and CMJ variables (positive: velocity, dip, time; negative: duration), and each wellness subscale displayed large/very large positive correlations with CMJ velocity. This was true for all sub—groups, although subtle differences existed between ages and positions. It was concluded that players' subjective wellness is a useful tool, ideally utilised within a broader monitoring scheme, for monitoring ongoing neuromuscular fatigue; which increased from week to week.

Keywords: recovery; wellness; Team sports; overtraining; performance; assessment.

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INTRODUCTION

Insufficient recovery can increase the risk of injury and illness, and negatively impact training and performance (18). Monitoring recovery status is important for practitioners wishing to optimise physical preparation therefore, as even low-level fatigue can hinder performance (18). Logistical issues with data-collection and inter-individual differences in recovery capacity (13) can make identifying early-stage fatigue challenging in practice however. Various hormonal, physiological, immunological and biochemical markers appear to be useful for determining overtraining (Overtraining Syndrome; OTS) (18) within clinical contexts, but appear to be less beneficial for the early detection of neuromuscular (NM) fatigue in applied situations. However, through the assessment of athletes' day-to-day NM status, training and recovery can be monitored acutely and longitudinally, and can be used to inform training. Indeed, data has shown that manipulating daily training based on players' NM fatigue status appears to improve on-field performance in collegiate football players (23). Physical performance tests are considered to be a criterion indicator of NM readiness (35), and the countermovement jump (CMJ) in particular appears to be both sensitive and reliable when monitoring fatigue status longitudinally (16). Data has shown that the CMJ appears to be more sensitive than cycle ergometry sprinting for measuring lower-body neuromuscular fatigue, perhaps due to greater contribution of the stretch-shortening cycle (28). Frequent physical testing can be difficult in practice given the complexity of team sports' busy regimens however. Logistical issues sometimes necessitate that affordable, non-invasive tools that facilitate effective monitoring without imposing substantial burden (administrative or physical) are favoured over alternative means with greater time and resource costs (22).

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One such tool is the assessment of perceived wellness, which is a non-invasive and cost effective method of assessing readiness that up to 84% of practitioners in team sports appear to collect (35). Links between athletes' perceived wellbeing and neuromuscular status underscore the use of such methods: mood disturbances accompany OTS (18), but may also be present during earlier stages of NM fatigue (30). Data indicates that perceived wellbeing exhibits dose-response relationships with acute and chronic training loads (31); however, no consistent associations between perceived wellness and physiological markers of fatigue appear to have been identified it seems. The Recovery-Stress Questionnaire for Athletes (RESTQ-S) and Multi-Component Training Distress Scale (MTDS) are two instruments that measure recovery-stress balance and psycho-behavioural responses to training stressors that appear in the literature (22). Within these tools, the subscales vigour/motivation, physical symptoms, non-training stress, fatigue, sleep, and general well-being appear to be sensitive to training-induced fatigue (31), and highlight important linkages between perceptual data and training strimuli.

Recent data from Gathercole et al. (14) highlighted reduced NM function and altered mood in response to 6-weeks of heightened training in elite female rugby players. While such data affirms linkages between perceived wellness and training stress, the artificiality of abnormal training and/ or deliberate overreaching (as means to invoke stress) in research contexts limits the applicability of such data to real-life situations — an area that Taylor et al. (37) suggests to need more work. Team sport athletes can also experience a host of wider physical and emotional stressors, such as fixture-density, physical contact and travel (27). In the absence of a naturalistic research environment, such factors that might not be fully represented in the literature to date. Time costs and perceived lack of sport-specificity of questionnaires such as the RESTQ-S might make them unpopular with practitioners who work in busy environments. Therefore, in practice, custom-made questionnaires (typically

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comprising 4-12 subscales) appear to be more common (37). Short-form, custom-designed questionnaires have been shown to respond to changes in objective training load during both a competitive season and an intensified training period in Australian football (4, 13). Mclean et al. (24) noted the usefulness of a 5-scale wellbeing questionnaire to assess recovery in professional rugby league similarly. From these studies, subscales such as 'fatigue' and 'general muscle soreness' appear to display the greatest responses to matches and preceding training loads.

Rugby union is a full contact sport characterised by intermittent, high-intensity activity and physical contact (11). Strength training, conditioning, and skills training are therefore important components of players' physical preparation (11). Fixture density and travel demands of the professional game however mean that players incur stress from multiple sources concurrently. Positional demands, training specificity, and inter-individual factors dictate that the physiological characteristics of players differ within a team (11). This might also manifest in players' responses to stressors, but has yet to be confirmed (1). The aims of this study were to assess the relationship between self-reported wellness and neuromuscular performance during a professional rugby union season, to assess the influence of both age and playing position on this relationship, and to identify changes in these parameters over a 12-week period. We expected that decreases in subjective wellness would reflect observable declines in NM performance (13), which we assessed via CMJ monitoring. Because experienced athletes might be more adept at quantifying perceived fatigue (38), wellness was expected to better reflect NM performance in older vs. younger players. Finally, the stresses of a professional season meant that players were expected to experience incomplete recovery week-to-week, which would manifest as ongoing declines in observed wellness and CMJ performance.

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METHODS

Experimental Approach to the Problem

In a longitudinal descriptive design, senior players from a professional rugby union club competing in the second tier of professional English rugby were monitored in normal training over 12-weeks of the competitive season. The club was interested in using subjective devices to determine players' responses to the stresses they face, owing to insufficient resources for more in-depth assessment. This study aimed to evaluate whether self-reported perceptions of wellness represents a useful indicator of NM status.

Subjective wellness, using a custom-designed short-form questionnaire, and CMJ, using a Linear Position Transducer (LPT), were assessed on the first training day of each week. This was usually a Monday, but occasionally a Tuesday, when games were played on Sunday rather than Saturday. Table 1 indicates the typical training schedule over the study period.

Declines in CMJ performance can indicate impaired NM capacity (15), and this study examined the relationship between changes in perceived wellness and CMJ performance, to assess whether wellness scores are sensitive to NM fatigue. Week-on-week changes and changes from baseline—in wellness and CMJ—were also assessed. Separate correlation analyses were conducted for forwards and backs, and for 'older' (≥25 years) and 'younger' (<25) players, to identify whether individual characteristics influenced these associations. These age thresholds were chosen as they represented existing 'old' and 'young' groupings at the club, which were used for allocating duties, social purposes, and for informal competition within the team.

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. **Table 1 about here**

Subjects

37 male players (mean ± *SD*); age 25.94 ± 4.10 years, stature 186.13 ± 8.51 cm, mass 103.82 ± 13.68 kg participated in this research, which took place within their regular training schedule. Players were accustomed to documenting perceived fatigue and regularly performed CMJs within training, therefore additional familiarisation was deemed unnecessary. Research was approved by the club and by Sheffield Hallam University Ethics Committee, and participants were fully briefed about the benefits and risks of the study prior to giving informed consent. A total of 279 data-entries for wellness, and 148 for CMJ were completed over the 12-weeks.

Procedures

Wellness

Players gave subjective ratings for five subscales of 'wellness', comprising three physical ('general fatigue/vigour', 'upper-body soreness', 'lower-body soreness'), and two lifestyle-related domains ('mood', 'sleep quality/duration'). Each was quantified on a 5-point Likert scale, whereby 1AU represented the lowest and 5 AU the highest possible rating of wellness. The sum of scores from the five subscales represented an individual's 'total wellnesses for a given day (score out of 25 AU). Subscales reflected those reported as sensitive to objective training load (24). Because of the physical nature of rugby, and the fact that Mclean et al. (25) noted 'general muscle soreness' as a potentially important subscale, the current study included 'upper-body soreness' and 'lower-body soreness' as separate subscales, to determine whether these items displayed different relationships with CMJ performance

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(which involves primarily lower-body musculature). The questionnaire was typical of common practice in team sport, where information must be gathered with minimal administrative burden (35). Despite lacking empirical validity, many such tools appear to be trusted by practitioners (35), and it was hoped that this study may provide some ecological validity for this approach in professional rugby.

Players entered data privately at their homes, at around 07:30, before any scheduled activity and within 60-minutes of waking. To minimise adherence demands, questionnaires were sent to players' mobile devices each morning via a web-based platform (Google Docs ™), and the ratings of others, or their own previous inputs were not visible to them. Data from all players were consolidated to a single database. To determine reliability of the wellness document, data were analysed from two similar weeks prior to the study period (13). These weeks followed a one-week taper, with no training being performed in the 24-hours preceding data-collection, therefore theoretically represented scores in the absence of substantial fatigue. Intraclass correlation coefficients (ICC) and 95% confidence intervals (CIs) calculated to indicate test-retest reliability were ICC = 0.87 (0.76, 0.93), and typical error (expressed as CV %) was 6.70%. Post-taper scores were used as baseline scores, representing time-point 1 for subsequent comparison.

CMJ

CMJ testing was conducted using the LPT, at approximately 08:30, prior to players' Strength and Conditioning training. Following a standardised warm-up of self-myofascial release, dynamic stretching and a bodyweight soft-tissue circuit, players completed a single set of five repeated CMJs with a 20kg barbell (Eleiko, Halmstad; Sweden), un-racked from sternum height, in the 'high-bar' position across the upper trapezius. Repeat CMJs may better identify

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NM fatigue than single jumps (8), and research by Sheppard et al. (35), and Hori and Andrews (20), suggest CMJs with a 20 kg bar are particularly reliable (CV% = 1.3-9.4%), especially for measures of peak velocity (CV% = 1.1-4.6%, TE = 0.01 $m \cdot s^{-1}$). The only instructions to players were to perform repeated jumps with maximum effort. Depth and speed of descent were self-selected.

An LPT (GymAware PowerTool ™; Kinetic Performance Technology, Canberra; Australia) was secured to the floor directly below the squat rack, and the tether extended vertically to attach to one collar of the barbell. The GymAware™ technology is particularly reliable for distance (TEE = 0.00 m) and velocity (TEE = 0.01 $m \cdot s^{-1}$) measurements (42). The LPT recorded various CMJ metrics, including: Peak Velocity ($m \cdot s^{-1}$) (highest concentric velocity achieved), Dip (m) (depth of eccentric descent), Duration (s) (time taken for both eccentric and concentric phase), and time to peak velocity (s) (time taken to achieve peak velocity). Metrics were chosen to represent measures of CMJ outcome *and* strategy (15). To attenuate fatigue-induced declines in concentric force, players should not adjust strategy, and changes in eccentric function appear particularly sensitive to NM fatigue (15). Reduced eccentric displacement has been observed in fatigued handball players (38), as have increases in repetition duration with snowboard athletes (17). Dip and time variables were therefore included as potential indicators of altered strategy in addition to peak velocity as an output measure (15). Observation was maintained to ensure no tilting of the barbell, which could influence readings. To ensure measurements reflected players' ability to repeat high-intensity NM activity, the mean reading across all five repetitions was taken as the outcome measure. Using maximum values may not reflect fatigue-induced changes over the course of five repetitions, and using mean values rather than maximum values, enhances the probability of the outcome reflecting an athlete's 'true score' by ~10:1 (5).

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The LPT was connected via Bluetooth to a mobile tablet device (iPad™; Apple, California; US) which displayed velocity statistics following each jump. The LPT was zeroed to participants' stature prior to each trial. Following each set, players were informed of the mean peak velocity achieved, and those unable to perform maximum effort CMJs on any given day, due to minor injury, were excluded from testing.

CMJ reliability increases over multiple sets (36), however time constraints within the club environment made only a single set per player possible each session. CMJ testing was performed consistently at around 08:30, due to the reduced variability observed at this time (36). CMJ between-day reliability statistics (ICC and 95% CIs), determined following taper and 24-hour absence of training, were as follows. Peak velocity: ICC = 0.92 (0.84, 0.96), CV% = 1.50%; Dip: ICC = 0.82 (0.66, 0.91), CV% = 15%; Duration: ICC = 0.46 (0.13, 0.70), CV% = 14.80%; Time to peak velocity: ICC = 0.91 (0.83, 0.96), CV% = 6.10%.

Statistical Analysis

For this study, data were analysed post season. However, as is common practice within rugby, staff used wellness data during the season as part of ongoing training load management. Statistical analysis was conducted using IBM SPSS for Windows (version 24). Data were analysed for the whole squad, before being split by age (older: *N* = 23, mass = 103.54 ± 14.85 kg, height = 186.88 ± 7.54 cm, age = 27.67 ± 1.60 years; younger: *N* = 14, mass = 104.29 ± 11.94 kg, height = 184.86 ± 10.13 cm, age = 23 ± 1.18 years), and then position (forwards: *N* = 20, mass = 113 ± 8.37 kg, height = 190.20 ± 8.57 cm, age = 26.85 ± 2.60 years backs: *N* = 17, mass = 94.17 ± 11.22 kg, height = 181.61 ± 5.86 cm, age = 25.28 ±

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2.76 years). To minimise potential bias from missing data, analyses used players' scores as a percentage change from baseline: (observed measure – baseline measure) / baseline measure.

Within-participant correlations and 95% CIs were calculated between changes in wellness and CMJ measures, and between changes in each particular wellness subscale and changes in CMJ peak velocity (3). It is common for research making longitudinal measurement of subjective and objective variables to proceed by conducting Pearson's correlation analysis on combined data across all time-points, or by evaluating each individual separately. However, such approaches may violate the assumption of independence, and diminish power. The within-participant approach acknowledges that repeated measures are taken from the same individuals and, because analysis is based upon the correct degrees of freedom, the statistical power is increased (21). The calculated within-participant correlation coefficients (r) were interpreted as: small: r = 0.1–0.29, moderate: r = 0.3–0.49, large: r = 0.5–0.69, very large: r = 0.7–0.89, near perfect: r = 0.9–0.99 (19, 33). To assess differences between correlation coefficients for independent groups (forwards vs backs; older vs younger), Fisher's r to z calculation was used to convert each coefficient into a z score, subsequent to comparison (33).

Due to issues with parametric assumptions, Wilcoxen Signed-Rank tests assessed changes in wellness and CMJ. Data from each week were compared to baseline, and to the preceding week, with significant differences defined as $p \leq 0.05$. Data are presented as mean ± 95% confidence interval (CI) unless otherwise indicated. Effect sizes (ES) were calculated for each comparison ($r = Z \div \sqrt{\text{N}}$) and interpreted as 0.10: small, 0.30: medium, 0.50: large

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effect (6). Mann-Whitney tests were used to compare overall raw wellness and CMJ velocity data across independent sub-groups of players.

RESULTS

Mean wellness and peak velocity for each position and age-group over the study period are presented in Table 2, and given as mean ± *SD*. Forwards displayed higher mean wellness than backs both at baseline (forwards 19.90 ± 1.84 AU; backs 18.71 ± 1.89 AU) and overall (forwards 17.37 ± 3.56 AU; backs 16.84 ± 3.15 AU), whereas backs achieved greater peak velocity (2.80 ± 0.10 $m \cdot s^{-1}$ at baseline and 2.67 ± 0.17 $m \cdot s^{-1}$ overall; compared to 2.74 ± 0.12 $m \cdot s^{-1}$ and 2.65 ± 0.20 $m \cdot s^{-1}$ for forwards). However, none of these differences reached statistical significance. There was a similar pattern between ages, as although not significantly so, older players exhibited higher ($p = 0.05$) wellness scores (19.39 ± 1.91 AU at baseline, and 17.36 ± 3.29 AU overall; compared to 19.29 ± 1.87 AU and 16.71 ± 3.56 AU), but lower peak velocity than younger players (2.75 ± 0.14 $m \cdot s^{-1}$ at baseline and 2.64 ± 0.20 $m \cdot s^{-1}$ overall; compared to 2.79 ± 0.08 $m \cdot s^{-1}$ and 2.68 ± 0.17 $m \cdot s^{-1}$ for younger). For all sub-groups, both wellness and velocity were reduced from baseline across the 12-weeks (see below).

Table 2 about here

Wellness

Figure 1 about here

Figure 2 about here

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Wellness at each time-point is displayed in figure 1, and figure 2 gives data for each subscale. All subscales followed similar trends, however the widest week-to-week fluctuations were seen for upper-body, lower-body and fatigue. Whilst forwards displayed higher wellness overall (Table 2), this was not the case at every time-point. Figure 3 shows that at time-points 3, 7, and 9, backs' wellness exceeded that of forwards.

Figure 3 about here

Figure 4 gives wellness as percentage change from baseline. All time-points except time-point 12 showed significant decreases from baseline ($p \leq 0.01$), and a declining trend was observed. Large effects existed for time-points 4 (-11.00 %, CIs: -6.2- -17.16 %, ES = 0.50), 6 (-13.13 %, CIs: -18.8- -7.46 %, ES = 0.50), 8 (-12.30 %, CIs: -5.89- -18.15 %, ES = 0.51), 10 (-21.80 %, CIs: -14.99- -28.61 %, ES = 0.59), 11 (-14.04 %, CIs: -7.58- -20.51 %, ES = 0.54), and 13 (-16.13 %, CIs: -10.06- -22.19 %, ES = 0.62). Increases in wellness from time-points 10 to 11 (7.75 %, CIs: 7.41-8.10 %, $p = 0.05$), and 11 to 12 (13.29 %, CIs: 11.75-14.84 %, $p < 0.01$) were significant, and ES of 0.30 and 0.53 suggest moderate and large effects respectively (3). Whilst not statistically significant, the ES (0.51) for the wellness decrease between time-points 12 and 13 also suggests a large effect.

Figure 4 about here

CMJ

Figure 5 about here

Peak velocity was lower than baseline at all time points and, like wellness, declined over the 12-weeks. Figure 5 shows velocity as a percentage change, with time points 5 (-5.0 %%, CIs: -9,19- -1.77 %, $p = 0.03$), 6 and 7 (time point 6: -3.82 %, CIs: -6.53- - 1.11 %, $p < 0.01$; time point 7: -7.43 %, CIs: -10.41- -4.44 %, $p < 0.01$), 9 and 10 (-6.58 %, CIs: -9.07- -4.09

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%, $p < 0.01$, and -5.61, CIs: -8.18- -3.03, $p < 0.01$ respectively), 11 (-3.93 %, CIs: -6.89- -0.96 %, $p = 0.02$), 12 (-6.07 %, CIs: -9.00- -3.14 %, $p < 0.01$), and 13 (-3.52 %, CIs: -6.22- -0.81 %, $p = 0.02$) showing significant decreases from baseline. These time points showed large effects, indicated by ES > 0.5 (3). Time points 8 (+5.61 %, CIs: 3.32-7.89 %, $p = 0.02$) and 9 (-4.76 %, CIs: -1.98- -7.54 %, $p < 0.01$) showed significant changes from the previous, with ES of 0.54 and 0.60 respectively. Time point 8 showed a significant *increase* in velocity from time point 7, whilst time point 9 produced a significant *decrease* relative to time point 8.

Associations

A number of significant ($p \leq 0.05$) relationships were identified between changes in wellness and CMJ variables. Very large within-participant correlations existed between changes in total wellness and dip (r = 0.80, 95% CIs = 0.72-0.86, $p < 0.01$), and between wellness and time to peak velocity (r = 0.74, 95% CIs = 0.63-0.82, $p < 0.01$). A large positive correlation existed between wellness and CMJ peak velocity (r = 0.67, 95% CIs = 0.54-0.76, $p < 0.01$), whereas a significant negative association was observed between changes in total wellness and duration (r = -0.62, 95% CIs = -0.49 - -0.72, $p < 0.01$). Of the individual wellness subscales, changes in sleep displayed a very large positive correlation with improvements in CMJ velocity (r = 0.86, 95% CIs = 0.75-0.92, p < 0.01), whilst fatigue (r = 0.67, 95% CIs = 0.53-0.78, $p < 0.01$), upper-body (r = 0.67, 95% CIs = 0.51-0.78, $p < 0.01$), lower-body (r = 0.69, 95% CIs = 0.54-0.80, $p < 0.01$), and mood (r = 0.62, 95% CIs = 0.44-0.75, $p < 0.01$) all showed large positive relationships with velocity.

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By position

Within-participant correlations for forwards were very large between wellness and dip (r = 0.72, 95% CIs = 0.59-0.81, $p < 0.01$), and large between wellness, velocity (r = 0.56, 95% CIs = 0.33-0.70, $p = 0.03$), and time to peak velocity (r = 0.68, 95% CIs = 0.51-0.80, $p < 0.01$). Each individual subscale displayed large and significant positive correlations with changes in CMJ velocity. By comparison, for backs, the correlation between wellness changes and changes in peak velocity were very large (r = 0.78, 95% CIs = 0.65-0.86, $p < 0.01$), whereas the relationships between dip (r = 0.63, 95% CIs = 0.45-0.76, $p < 0.01$), time to peak velocity (r = 0.65, 95% CIs = 0.47-0.77, $p < 0.01$), and the negative correlation between duration and changes in total wellness (r = -0.63, 95% CIs = -0.45 - -0.76, $p < 0.01$), were all large. The relationship between wellness changes and changes in CMJ velocity for backs was significantly stronger than for forwards ($p = 0.01$). For backs, each wellness subscale showed a very large correlation with changes in velocity, and these correlations were all significantly stronger than those observed for forwards (fatigue: $p = 0.01$, upper-body: $p = 0.03$, lower-body: $p = 0.03$, sleep: $p = 0.03$, mood: $p = 0.01$).

By age

Older players displayed very large positive correlations between changes in wellness and both dip (r = 0.77, 95% CIs = 0.66-0.85, $p < 0.01$), and time to peak velocity (r = 0.72, 95% CIs = 0.59-0.81, $p < 0.01$). A large positive correlation also existed between wellness and peak velocity (r = 0.60, 95% CIs = 0.44-0.73, $p < 0.01$). Each wellness subscale showed a large correlation with changes in CMJ velocity. For younger players, the association between changes in wellness and velocity was very large (r = 0.70, 95% CIs = 0.55-0.81, $p < 0.01$),

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whereas wellness changes showed large positive correlations with changes in dip (r = 0.64, 95% CIs = 0.46-0.77, $p < 0.01$), time to peak velocity (r = 0.68, 95% CIs = 0.52-0.79, $p < 0.01$), and were negatively correlated with CMJ duration (r = -0.68, 95% CIs = -0.52 - -0.80, $p < 0.01$). As with older players, each wellness subscale showed a large positive correlation with changes in CMJ velocity. The correlation between changes in wellness and CMJ dip was significantly stronger for older players compared with younger ($p = 0.05$), and the negative relationship between wellness and CMJ duration changes was stronger for younger than older players ($p = 0.05$).

DISCUSSION

The aims of this study were to assess the relationship between self-reported wellness and neuromuscular performance (indicated by CMJ) during a professional rugby union season, to assess the influence of both age and playing position, and to identify changes in these parameters over a 12-week period. Although wellness scores were generally around 70% of the maximum potential value, both wellness and CMJ performance were reduced from baseline at all time points, and showed declining trends throughout. This suggests the presence of accumulating fatigue, and incomplete week-to-week recovery.

As predicted, significant associations existed between changes in wellness and CMJ variables. Because reductions in CMJ velocity and/or a reduced eccentric component appear sensitive to NM fatigue (15), these results suggest wellness scoring, collected using a short-form questionnaire, is useful for monitoring NM status during a professional rugby season. Our results reflect similar findings for a 9-item questionnaire in Australian football (14), and a 5-item scale in professional rugby league (24).

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NM fatigue may alter stretch-reflex sensitivity and diminish muscle-tendon stiffness (40). Indeed, decreased eccentric displacement and utilization have been observed in fatigued athletes (39), potentially alongside increased CMJ duration (15). Fatigued athletes may require more time to produce sufficient eccentric force to maintain the required concentric output (39). The very large association between wellness and dip (r = 0.80, 95% CIs = 0.72-0.86), and the strong negative correlation between wellness changes and CMJ duration (r = -0.62, 95% CIs = -0.49 - -0.72) suggest NM strategy may have been altered in response to fatigue. Increases in total CMJ duration, and reduced depth of eccentric decent therefore accompanied declines in self-reported wellness. These findings support the notion that neuromuscular and stretch-shortening efficiency may have been compromised at the same time as wellness scores were reduced. Fatigue-induced reductions in dip depth, and possibly flight time (15), limit the distance of each jump, which may have masked reductions in eccentric velocity. Previous work has demonstrated similar patterns, and suggests CMJ depth may be sensitive to fatigue (38).

All wellness subscales showed large positive correlations with changes in CMJ velocity, suggesting their sensitivity to NM fatigue, and utility within a wellness-monitoring questionnaire. Correlations between upper-body symptoms and jumping performance that we observed may appear surprising. However, because upper-body musculature is less substantial than lower-body, it may be less resilient, and possess a lower threshold above which fatigue cannot be sustained solely peripherally (32). This would suggest upper-body fatigue of lesser magnitude may be required before effects are seen on a more global level

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The sensitivity of particular CMJ measures to NM fatigue may be population specific (28), and older players saw stronger (*p* = 0.05) positive correlations between changes in wellness and dip (r = 0.77, 95% CIs = 0.66-0.85) than younger players (r = 0.64, 95% CIs = 0.46-0.77). Whilst not significantly different between groups, the correlation between wellness and velocity was 'large' for older (r = 0.60, 95% CIs = 0.44-0.73), compared with 'very large' for younger players (r = 0.70, 95% CIs = 0.55-0.81), and the negative correlation between wellness and CMJ duration was significantly stronger (*p* = 0.05) for younger players (r = -0.68, 95% CIs = -0.52 - -0.80), than the non-significant correlation observed for older players. Because low-frequency or peripheral contractile fatigue may be partially overcome by changes in motor unit recruitment and/or neuron firing frequency (10), these results may suggest experienced players are more adept at altering technique (by decreasing depth, and speed of eccentric decent) to attenuate performance (velocity) declines (15). Even if CMJ velocity is better maintained, technical or temporal compensations can be deleterious to skilled movement (i.e. on-field movement), and NM fatigue has altered high-speed running in Australian football, leading coaches to perceive poor performance (7). Moreover, if under-recovery persists, low-level fatigue could progress to central breakdown (30).

Backs displayed significantly stronger (*p* = 0.01) positive correlations between changes in total wellness and CMJ velocity than forwards (backs: r = 0.78, 95% CIs = 0.65-0.86, forwards: r = 0.56, 95% CIs = 0.33-0.70), as well as between each wellness subscale and velocity (fatigue: *p* = 0.01, upper-body: *p* = 0.03, lower-body: *p* = 0.03, sleep: *p* = 0.03, mood: *p* = 0.01). However, whilst not significantly different, forwards showed 'very large' positive correlations between wellness changes and changes in dip (r = 0.72, 95% CIs = 0.59-0.81), whereas this relationship was 'large' for backs (r = 0.63, 95% CIs = 0.45-0.76).

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Moreover, the negative association between wellness and CMJ duration was 'large' for backs ($r = -0.63$, 95% CIs = -0.45 - -0.76), but did not reach significance for the forwards group.

These findings may be attributable to the age distribution of players at the club, or the nature of fatigue sustained across positions. The time-course of SSC recovery is non-linear and dependent upon the fatiguing stimulus, and re-optimisation of neural strategy takes time to develop (15). The results may suggest forwards were typically less neurally fatigued, thus wellness changes could be matched by re-optimisation of technique; whereas backs' fatigue may have been too substantial to overcome in this way, such that velocity suffered to a greater extent. Gastin et al. (13) found players with higher maximum speeds took longer to recover following Australian Football, and backs are typically faster individuals within rugby. Sprinting and high-velocity eccentric muscle-actions invoke substantial muscle damage (12); therefore, the nature of their tasks, and potential differences in muscle fibre composition or architecture, may mean backs suffer greater muscle damage, such that they take longer to recover from, than forwards (25). The observation that, for backs compared with forwards, each wellness subscale showed significantly stronger relationships with changes in velocity may support this suggestion, as it is hoped that greater levels of fatigue would be reflected by larger fluctuations in wellness criteria. Testing later within the week, further from the previous game, may have produced different results, and in a study of professional rugby league players, both neuromuscular and perceptual measures returned to baseline within ~4 days following a match (24). Research objectively quantifying fatigue-responses between positions would be useful to indicate whether different positions warrant different training and recovery practices.

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Declining trends in wellness and CMJ velocity suggest increasing fatigue as the study progressed; and incomplete recovery during each week. Both measures appear sensitive to fluctuations in stress, for example time point 7 followed a difficult match against the league champions, which was reflected by large decreases in scores (wellness: -15.96 %, CIs: -7.97- -23.95 %, ES = 0.46; velocity: -7.43 %, CIs: -10.41- -4.44 %, ES = 0.61). The following week saw several loan players introduced, to rest regular first-choice players. This might explain the improved velocity scores between time points 7 and 8 (+5.61 %, CIs: 3.32-7.89 %, ES = 0.60), and suggest that 'rotation' had the desired consequence of facilitating recovery amongst participants of the study.

No fixture was played between time points 11 and 12, with players training as normal. Wellness at time point 12 rose significantly from time point 11 (+13.29 %, CIs: 11.75-14.84 %, ES = 0.53), and approached baseline level. However, peak velocity showed no concomitant increase (ES = 0.04). Although Coutts et al. (9) observed improvements in psychological *and* performance measures following a 7-day taper in rugby league players their study involved only a 6-week overload. In the present study, players endured a more substantial period of under-recovery, which may take longer to recover from. Players also continued to train during the week, therefore notwithstanding the psychological break, NM stress was still being incurred. These findings are in contrast to Mclean et al. (24), who observed perceptual and performance measures consistently returning to baseline after 4 days post-match throughout a rugby league season. However, that study focussed primarily responses within each macrocycle, whereas the current investigation may highlight increasing fatigue responses to matches as a season progresses. Potential differences in fitness, rugby code, and playing time may also explain the divergent findings. In particular, Mclean et al (24) studied top-level rugby league players, contrasting this investigation into second-tier

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English rugby union, where the club lacked the playing resources to regularly rotate players. Whilst there are clear benefits to 'bye' weeks within a season (13), in some instances, more than a single-week may be required to restore NM capacity when substantial fatigue is involved (2). These results also suggest the importance of appropriate periodisation, and maximising opportunities to unload players during a season.

Despite the overall correlations, after time point 10, changes in wellness were not necessarily matched by velocity. It is possible that the wellness document may have been most sensitive to peripheral or muscular symptoms; whereas high-intensity stretch-shortening activities, such as repeat CMJs, require CNS recovery. Indeed, Roe et al. (28) suggested that whilst CMJ measures had good sensitivity, a 6-item wellbeing questionnaire had 'poor' sensitivity to detect changes in NM fatigue, owing to between-day CV% exceeding the smallest worthwhile change. Cormack et al. (8) proposed the existence of a threshold capacity to handle repeated high-intensity activity, after which NM overreaching presents. Players potentially surpassed this threshold as the season progressed, and because peripheral symptoms dissipate more quickly than restoration of NM capacity (2), wellness may have responded to recovery on a peripheral level, even where NM fatigue persisted. If true, this lends credence to relying not solely on wellness data, but performing comprehensive assessments of players where possible. The club in the present study, along with many clubs at a similar level, lack time and resources to perform regular (i.e. daily) CMJ testing, and subjective wellness may nonetheless provide a useful insight (27). The results suggest in favour of self-reported wellness as an indicator of fluctuations in NM fatigue, although the suggestion that weekly CMJ assessments are also performed (24), remains sensible. An opportunity for future research may be to examine which measures are most important to practitioners to give an indication of potential negative consequences when these responses differ.

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To the best of our knowledge, this is the first investigation of a custom-made wellness questionnaire during an ongoing season in professional rugby union. It has demonstrated support for this commonly employed approach to fatigue monitoring, and highlights its utility for predicting NM capacity. A trend of under-recovery was identified, with both wellness and NM capacity persisting beneath baseline levels, and decreasing over the 12-weeks. However, whilst the document appears sensitive to changes in peripheral or muscular fatigue, relationships between wellness and performance output seemed to deteriorate as the study progressed (figures 4 and 6) (18). This may suggest a dichotomy between wellness and fatigue, whereby perceived wellness improves more rapidly in response to stress-reduction than does NM capacity. Differences between forwards and backs, and between older and younger players, may suggest differences in NM responses to fatigue, and/or levels of fatigue incurred, and indicate potential benefits for the different treatment of these groups. If groups diverge in terms of fatigue incurred, they may require different training prescription (11), and wellness monitoring is useful only for those for whom wellness changes correspond to altered fatigue state.

Two principal limitations exist with this study. The first limitation concerns sensitivity to NM fatigue. The efficacy of CMJ monitoring to detect NM fatigue in young players (~19 years) has been questioned during a rugby pre-season, when strength and velocity improvements are being made (29). However, the present study was conducted in senior players (~26 years) during a professional rugby season, when such physical adaptations are unlikely to manifest (1). More notably, only selected CMJ metrics were analysed, and whilst these were chosen deliberately to represent performance outcome *and* strategy, including additional measures may have provided a fuller indication of fatigue (17, 27, 29). The most fatigue-sensitive CMJ

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measures remain unclear (17), but alternative metrics may have displayed closer relationships, and provided stronger suggestions in favour of wellness monitoring. Moreover, increasing the number of CMJ trials at each time point may have increased measures' reliability, and further enhanced the capacity to detect meaningful change. Time- and eccentric-related variables appear less reliable than concentric output (15), and including metrics such as peak and mean power and/or force may aid the sensitivity to detect NM fatigue (27).

Moreover, because wellness and CMJ were assessed only once per week it was not possible to determine responses to training and recovery over the course of a week. Previous work has documented progressive improvements in self-reported wellness in the days following a game in Australian Football players (13), and observed returns to baseline for both perceptual and NM fatigue measures ~4 days after a professional rugby league match (23). Whilst within-week effects were not examined, the responsiveness of wellness questionnaires to acute and chronic training load has been well documented (31), and the current study sheds some light on the pattern of responses over 12-weeks of a season. Notably, we highlight strong relationships between changes in self-reported wellness and changes in CMJ measures of NM capacity.

A practical limitation surrounds player availability. Injury and other absences meant few players were tested at all time points, which reduced the power to detect significant results. Whilst a number of significant results were evident, statistical support for this form of monitoring, and differences between sub-groups in particular, may have been further

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increased with more data points. Finally, the findings of this study are specific to their context, and may not reflect the wider sporting environment. Future work should investigate similar wellness monitoring within different team sport settings; amongst athletes of varying experience, and at different stages of the competitive macrocycle.

PRACTICAL APPLICATIONS

Subjective wellness, assessed via a 5-scale questionnaire, appears sensitive to fluctuating stress during a professional rugby season; and represents a useful tool for monitoring players' NM fatigue. The downward trends observed, and responses at time point 12, indicate the psychological importance of bye weeks, and may suggest that more than a single week is preferential to restore NM function. Because incomplete recovery was seen week-to-week, practitioners should note the importance of appropriate periodisation, and regularly unload players to reduce the risk of overreaching. Where feasible, squad rotation may help offset recovery-debt; and the improvements in wellness and NM performance observed at time point 8, suggest in favour of this approach.

Wellness monitoring presumes honest, consistent reporting, and relies upon trust between all parties. Practitioners prescribing training based directly on wellness must be cautious, and recognise the potential for players misrepresenting wellness to manipulate subsequent workload. Interpretation must also be careful. Wellness is not standardised between individuals, and equivalent scores may not indicate equivalent fatigue. It is important to consider data in the context of each player, and to use relative *change* when interpreting longitudinal trends amongst groups.

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Notwithstanding the strong associations identified, wellness is simply one potential monitoring tool. Recovery rates differ (13), stress varies between players, and there may be disparity between individual and group data. Whilst wellness appears a useful metric, employing multiple tools is likely to provide a fuller picture of players' ongoing responses (13, 24). That said, data-collection must be rationalised in each context, and what is practical or useful will vary according to budget, time, and staffing. Where, as in the present study, substantial constraints exist, a practical solution may be to monitor daily wellness via a short-form questionnaire, yet periodically undertake more in-depth assessments. For clubs with greater resources, there is broader scope for collecting and analysing more data to illustrate objective loads, ongoing responses, and for using techniques such as velocity-based-training to provide bespoke training prescription based upon observed responses.

As experienced in the present study, players regularly suffer injury or are otherwise absent from training. This poses additional challenges for practitioners seeking to control stress and determine ongoing responses. Monitoring must be considered on an individual basis, and including an open-ended 'comments' section within a wellness questionnaire may be useful to highlight issues and initiate further discussion between players and staff. If including this qualitative component would not unsustainably stretch resources, the opportunity for players to forward additional unbounded information, may provide the most valuable insight into their capacity to cope.

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FIGURE LEGEND

Table 1: Weekly training schedule during the 12- week study period. Where games are played on Sundays, training for the week leading up to the match is conducted a day later than indicated

Table 2: Total wellness and peak velocity by position and by age; data are expressed as mean ± *SD*. No significant differences were observed between independent subgroups of age or position

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Figure 1: Mean Wellness (± 95% CI) for whole squad, from baseline (timepoint 1) to week 12.

Figure 2: Mean scores for each wellness subscale (± 95% CIs), from baseline (timepoint 1) to week 12

Figure 3: Mean Wellness (± 95% CI) for forwards and backs, from baseline (timepoint 1) to week 12.

Figure 4: Mean % change from baseline (± 95% CI) in total wellness. Timepoint 1 denotes baseline. ** indicates significant difference from baseline ($p \leq 0.01$). □ indicates significant difference from previous timepoint ($p \leq 0.05$)

Figure 5: Peak velocity as % change from baseline (± 95% CI) Timepoint 1 denotes baseline. * indicates significant difference from baseline (* = $p \leq 0.05$; ** = $p \leq 0.01$). □ indicates significant difference from previous timepoint ($p \leq 0.05$)

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Table 1: Weekly training schedule during the 12- week study period. Where games are played on Sundays, training for the week leading up to the match is conducted a day later than indicated. Testing was moved back one day at time-points 3, 6, and 11, due to the preceding game being played on a Sunday.

	MON	TUE	WED	THU	FRI	SAT	SUN
AM	***CMJ TESTING***, Full-body RT (Strength/hyp)(60min), Gym-based aerobic conditioning (20min)	Rugby (Units: 1hr, Team session: 45min)		Full-body RT (RFD /speed focus) (50mins)		RT and conditioning for non-selected players	
PM	Rugby (Units: 1hr, Team session: 45min)			Rugby (Units: 20min, Team run: 20min)		GAME + top up conditioning for substitutes	

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Table 2: Total wellness and peak velocity by position and by age; data are expressed as mean ± *SD.* No significant differences were observed between independent subgroups of age or position.

		Squad (*N* = *37)*	**Forwards (*N* = 20)**	**Backs (*N* = 17)**	**Older (*N* = 23)**	**Younger (*N* = 14)**
WELLNESS (AU)	**Baseline (±*SD*)**	19.35 (± 1.89)	19.90 (± 1.84)	18.71 (± 1.89)	19.39 (± 1.91)	19.29 (± 1.87)
	Overall (±*SD*)	17.14 (± 3.39)	17.37 (± 3.56)	16.84 (± 3.15)	17.36 (± 3.29)	16.71 (± 3.56)
PEAK VELOCITY ($m·s^{-1}$)	**Baseline (±*SD*)**	2.77 (± 0.12)	2.74 (± 0.12)	2.80 (± 0.10)	2.75 (± 0.14)	2.79 (± 0.08)
	Overall (±*SD*)	2.66 (± 0.19)	2.65 (± 0.20)	2.67 (± 0.17)	2.64 (± 0.2)	2.68 (± 0.17)

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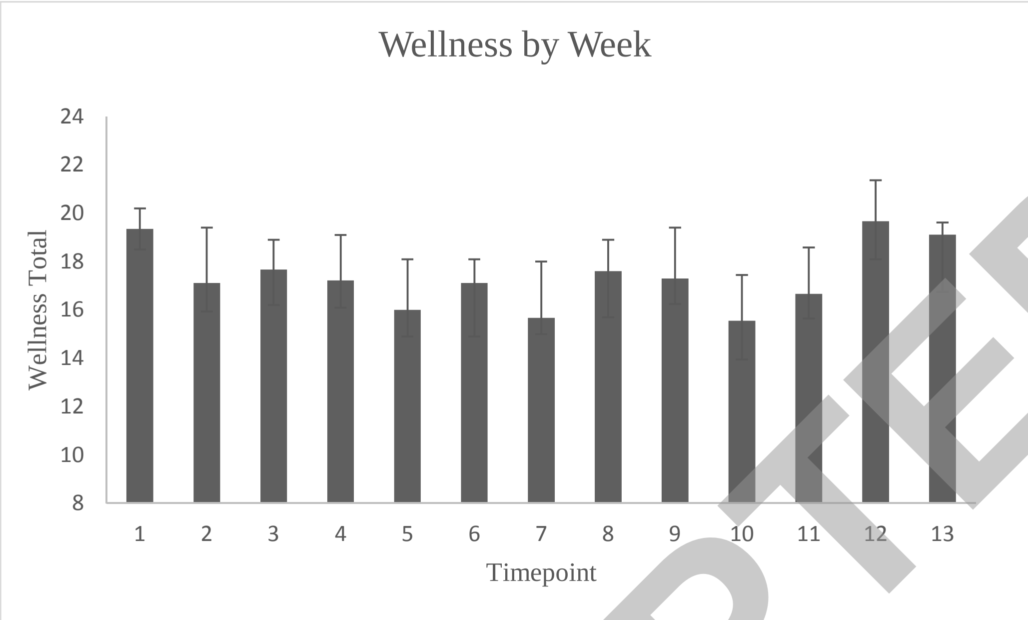

Figure 1: Mean Wellness (± 95% CI) for whole squad, from baseline (time point 1) to week 12.

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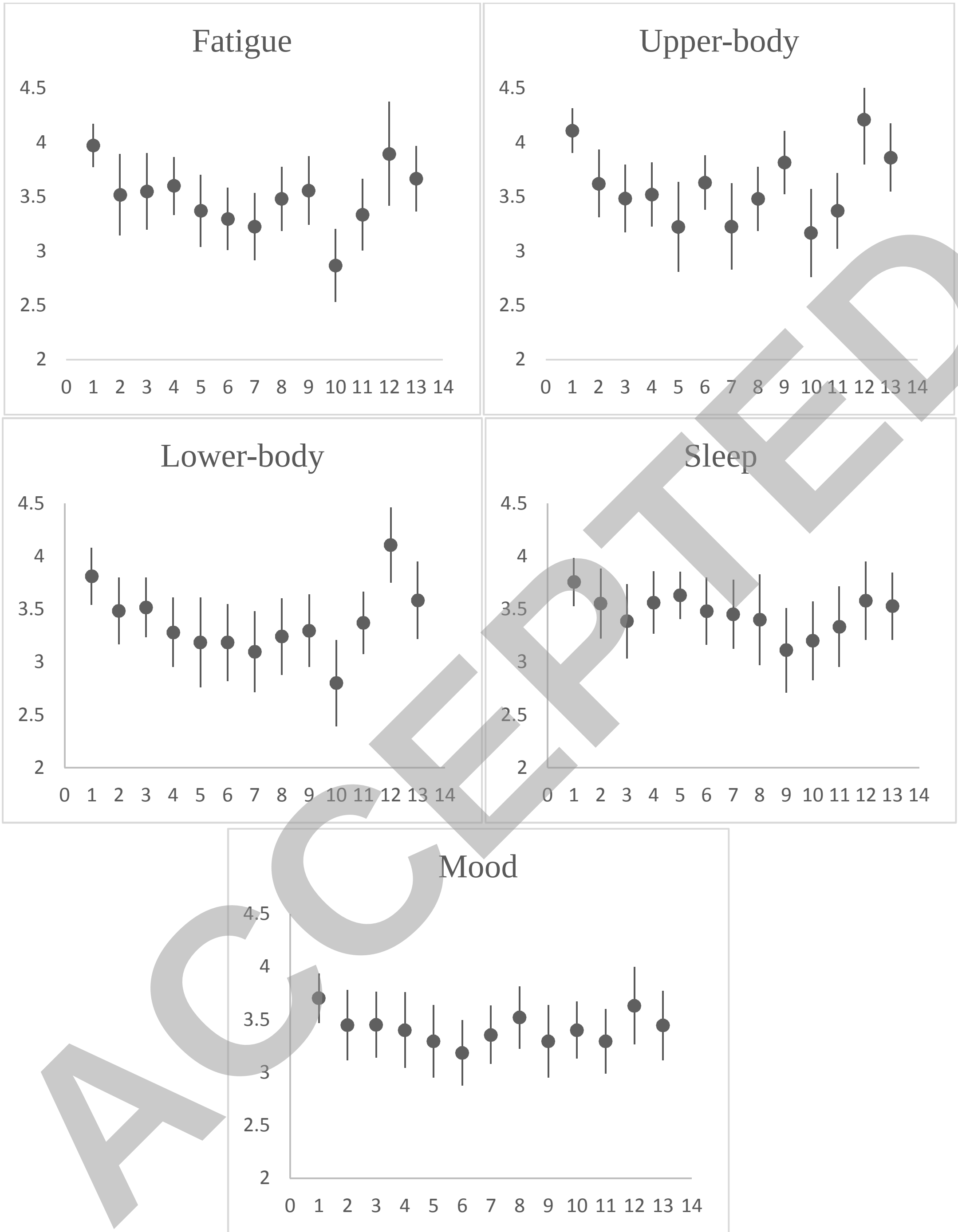

Figure 2: Mean scores for each wellness subscale (± 95% CIs), from baseline (time point 1) to week 12

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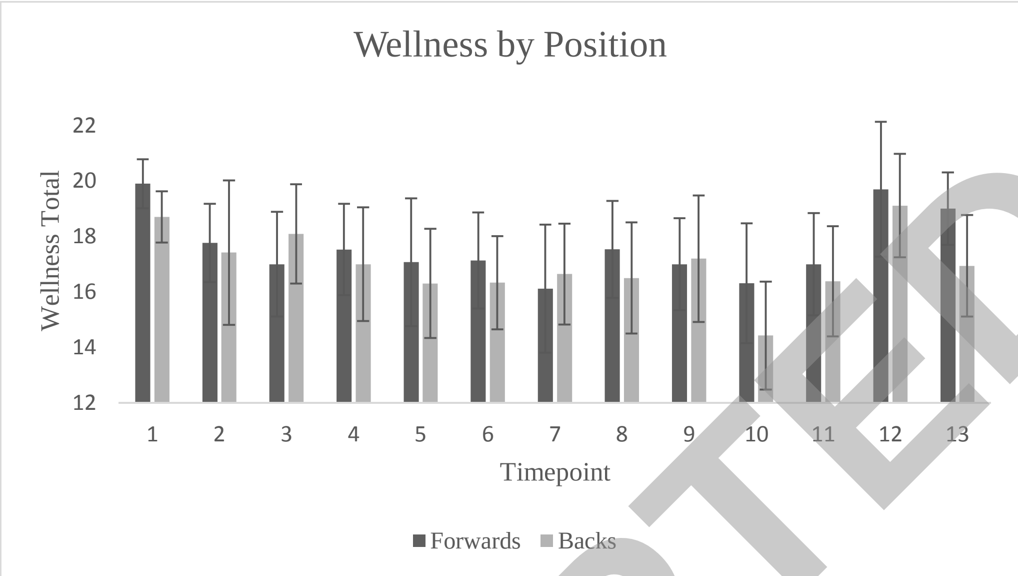

Figure 3: Mean Wellness (± 95% CI) for forwards and backs, from baseline (time point 1) to week 12.

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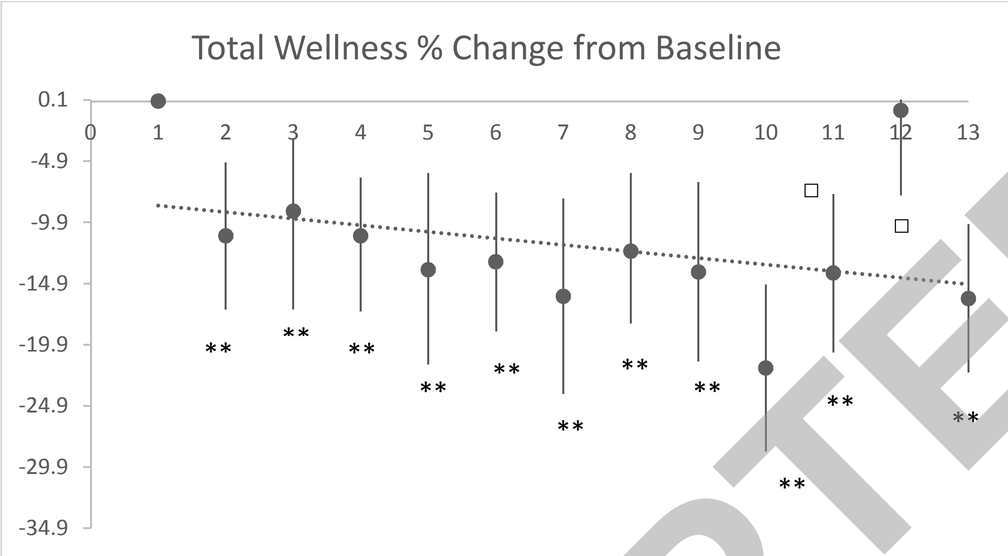

Figure 4: Mean % change from baseline (± 95% CI) in total wellness. Time point 1 denotes baseline. ** indicates significant difference from baseline ($p \leq 0.01$). □ indicates significant difference from previous time point ($p \leq 0.05$)

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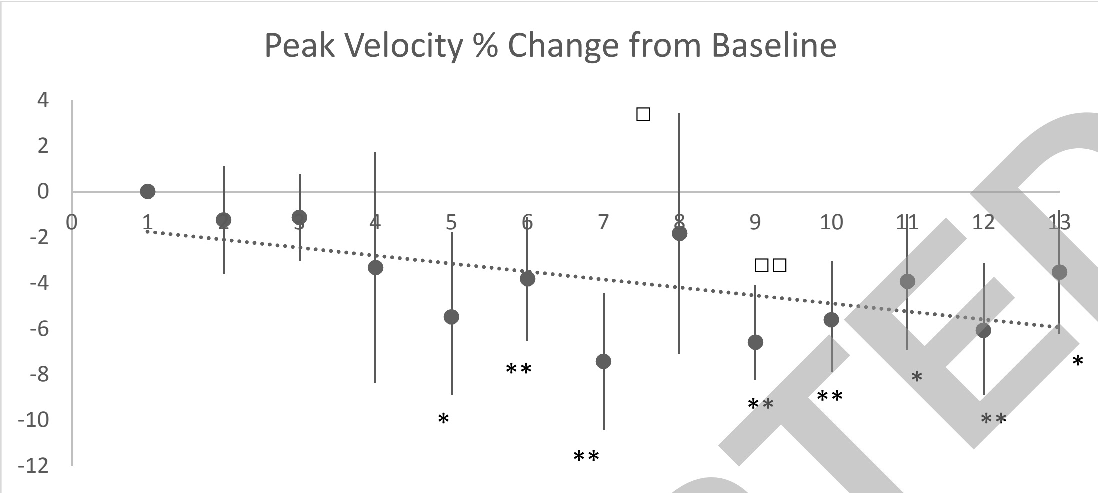

Figure 5: Peak velocity as % change from baseline (± 95% CI) Time point 1 denotes baseline. * indicates significant difference from baseline (* = $p \leq 0.05$; ** = $p \leq 0.01$). □ indicates significant difference from previous time point ($p \leq 0.05$)

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