MSc Strength and Conditioning

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THE INFLUENCE OF STRENGTH AND AEROBIC CAPACITY ON ATHLETES ABILITY TO RECOVER FROM A RUGBY UNION SIMULATION PROTOCOL

ABSTRACT

The study examined the influence of strength and aerobic capacity on ability to recover from NMF following a rugby union simulation protocol. 20 rugby union subjects were tested for strength markers through front squat, prone row and bench press and for aerobic capacity through a 30-15 intermittent fitness test. The subjects were then tested for baseline neuromuscular fatigue markers in a reactive strength index through (RSI), a drop jump (DJ), and countermovement jump (CMJ) prior taking part in the Bath University Shuttle Test (BURST). Following the BURST the subjects repeated the neuromuscular performance test battery consisting of the DJ and CMJ at 24hrs, 48hrs and 72hrs post BURST. The subjects were divided into high and low groups based on each individual physical marker for absolute strength relative to body mass and fitness using the median of the collected values. The BURST had a significant effect on all RSI repeated measurement and CMJ was significantly affected at 24hrs. Relative front squat strength, absolute prone row strength had a significant effect on subject's ability to recover post the BURST, and there was no significance found in either bench press measurement. The higher value groups had significantly higher neuromuscular performance on both RSI and CMJ compared to the lower groups in fitness, prone row strength and relative leg strength and slightly higher in all other measurements at baseline and repeated measurements.

KEY WORDS: Neuromuscular fatigue, significance, Absolute strength, relative strength, fitness, countermovement jump, reactive strength index

INTRODUCTION

Rugby union is an intermittent collision based sport with a significant physical demand (7,8). Developing participates physiological capabilities is a vital component in improving sports performance (2). As a performance team, the goal is to maximise physical development to give the athlete the best opportunity to succeed, and cope with the physical demand of the sport (23). Leading to a significant training demands placed on elite rugby union athletes, with increased training frequency, duration and intensity. Understanding the training response, and adaptation to stimulus is vital when considering performance, and injury prevention (11).

Fatigue in rugby union is complex and can have several possible mechanisms, making understanding of the cause is sometimes difficult to quantify. Fatigue has been defined by a decline in acute muscle force production, or failure to maintain power output (1,11,36). It can be influenced by different types of training stimulus, type of muscular contraction, intensity, frequency, duration of exercise or the athlete's physical qualities (14,22,31).

The magnitude of fatigue can vary dependant on muscular components, and central or peripheral nervous system responses. Due to the impact and high intensity of rugby union quantifying the factors leading to fatigue, it can make understanding and quantifying fatigue difficult (4, 40)

Various studies have researched into the effect of fatigue and its influence on Rugby Union performance. A study by Gabbett (2016) found that athletes with greater relative lower-body strength had the best tackling ability under fatigue. This study was supported by Johnston (2015) that reported players with higher anaerobic capacity and lower body strength had greater load during match play, and less reduction in post-match counter movement jumps (CMJ). A study by Hendricks and Lambert (2010) demonstrated the importance of tackling technique in reduction of injury. It was suggested that 61% of all rugby match related injuries were due to the tackle area, and tackle technique was a vital part of injury reduction. This coupled with Gabbett's (2016) findings of reduced tackling ability in weaker athletes is a strong rationale for the importance of understanding the demands and needs of physical capabilities in improved performance, and injury reduction.

Athletes with higher anaerobic capacity and better lower limb strength exhibited smaller changes in post-match creatine kinase. Furthermore, it has also been suggested that neuromuscular fatigue (NMF) and hormonal disturbance could be affected up to 36-60hrs post-match (39). This shows the significant role that physical qualities can have on rugby athletes, and how influential it can be for them to recover. However, there is little research to suggest what qualities influence NMF recovery post game, and thus there is a lack of understanding of the physical qualities needed to improve rugby related recovery.

Twist and Highton (2013) mentions that the best measurement of post-match fatigue for rugby is blood chemical markers as an objective measurement of homeostatic disturbance from match play. However due to the cost and expertise required, they suggest that a test of muscle function offers the most practical method to measure the extent of NMF experienced by rugby players. A measure of neuromuscular function has commonly been used to assess NMF in team sport above other indirect markers because its ability to monitor low-frequency fatigue (19,20,21,38). Research indicates jump variations are effective because they reflect stretch shortening cycle ability of the lower limb and gives the ability to measure fatigue (15). Roe et al., (2016) investigated the difference between using a CMJ or a 6s peak power cycle ergometer test and found that there was a significant change in CMJ in comparison to CET, justifying the use of CMJ to monitor NMF.

Research by Meylan et al., (2011) and McErlain-Naylor et al. (2014) suggested that altering the kinetics and kinematics of the CMJ has a drastic effect on the CMJ performance suggesting potentially that its use in monitoring neuromuscular fatigue and stretch shortening cycle is questionable. Reactive strength index and leg stiffness has been recognised as a reliable test for measuring NMF and SSC (17, 34). Reactive strength index (RSI) has been used as a reliable performance test in various team sport populations (26,34). Between day reliability and sensitivity of monitoring fatigue measures in rugby player has been shown as vital data in predicting injury and optimizing performance. Roe et al., 2016 suggested that mean power, peak power, contraction time and flight time were key metrics in measuring lower limb NMF fatigue.

There is a large body of evidence to suggest that rugby union induces significant NMF and muscle damage during match play, however they do not quantify what physical qualities can influence and reduce post-match fatigue. The aim of this study is to determine if different physical markers have an the athletes ability to recover.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

Markers of neuromuscular performance and a physical battery were assessed after natural break post competitive season, or with no weekend completive fixture. This created a seven day rest period prior to conducting the study. Participants were instructed not to take part in any other form of activity during the study. After the neuromuscular markers and strength testing scores were taken, 48hrs recovery was given to reduce any negative influencing of the Rugby simulation protocol. The Bath University Rugby Union Shuttle Test (27,28) was then conducted a standardized rugby union protocol to induce match demand fatigue. Following this, the participants were monitored for neuromuscular fatigue at 24, 48, 72hrs post testing.

SUBJECTS

Twenty male rugby union athletes (age 20.9±1.8, height 185.1±7.4,body mass 96.3±14.1) were recruited and volunteered to take part in the study. All participants competed in National 1 and BUCS Super League. Participants were provided with written and verbal information, and an understanding of the requirements prior to giving written consent. The study was approved by the St. Mary’s University Research Ethics Committee.

PROCEDURES

Preliminary Familiarization

Prior to the main trial, the participants attended a trial session to familiarize themselves with the BURST. In the session, the participants carried out the performance test (figure 2) and 30 mins of the test (figure 1) to accustom them to the exercise pattern. As part of their warm-up to the main test, they conducted 1 part of the BURST excluding the performance test.

Neuromuscular Fatigue Monitoring-

Counter movement Jump (CMJ) and Reactive strength index (RSI) using a drop jump (DJ) were used to monitor NMF through using an OptoJump system (microgate, Italy) and appropriate software. A standardised warm up was performed prior to maximal effort jumps. Following the warm up the participants performed a DJ from a standardised 30cm box 3 jumps 2 submaximal and a maximal effort (29). DJ first, followed by CMJ (37,38).

Subjects were required to place hands on hips, knees extended and a foot position of their own choice and proceed to jump as high as possible. The depth of the jump was down to the participant's discretion. In conjunction with previous literature researching NMF and CMJ peak power, mean power and flight time will be measured in the analysis. In this cohort, these metrics have shown to have acceptable sensitivity and reliability (coefficient of vitiation < 5%, CV <SWC) (17, 29).

To measure RSI participants performed a drop jump from a standardized 30cm box and RSI was calculated using an optojump system (microgate, Italy). The reliability of this protocol has been shown in previous research to work to good effect. A ground contact time of >0.3s was required to standardize the test. (5,12,25).

$$RSI = \frac{\text{Jump height (cm)}}{\text{Ground Contact Time (s)}}$$

Equation 1

Physical Testing Battery

The testing battery consisted of strength profiling and 30-15 intermittent fitness tests. 3RM strength testing will be conducted with front squat, prone row, bench press, CMJ and DJ.

Strength Testing- The exercise selection came as part of the regular programme and all athletes are experienced in these lifts, being a common theme of their programming. All lifts will be standardized to ensure validity. Participants took part in a standardized warm up protocol followed 2 sets of 5 repetitions at near 3RM load. They then have five attempts to attain a 3RM. The front squat protocol requires the athlete's thigh to be at least parallel with the ground and no excessive lumber flexion, which will be determined by the lead researcher (strength and conditioning coach). With the bench press, the participants will determine a self-selected grip that is most comfortable. The barbell must touch the chest and return to full unassisted lockout with no excessive lumber flexion/extension for it to be recorded. In the prone row test, participants are required to lay prone on the bench, will arms fully locked out and barbell on the floor. For the score to be recorded the barbell must touch the top of the bench. (14,29).

30-15 intermittent Fitness Test- The test consisted of 30s shuttles over a 40m distance with 15s recovery between efforts. The test begins at 8km.h and increases by 0. 5km.h at each successive running shuttle. The speed of the test was controlled by a pre-recorded audio (3,6) that informs the participants of appropriate intervals via a beep. The participants have a 3m 'safe zone' they are required to be within before the beep, these are placed at each end and middle of the test. At the end of the 30s the participants are instructed to walk to a specific line before the next stage commences. The test terminates when the participants are unable to maintain the speed, and reach the 'safe zone' before the beep on 3 consecutive occasions (6, 32).

Bath University Rugby Union Shuttle Test

The physical demands of elite rugby union can be repeated under controlled measures using the Bath University Rugby Union Shuttle Test (BURST) (figure 1). Participants took part in a 10-minute warm up including 5 minutes of jogging and stretching followed by a 315s period of the BURST test, which excludes the performance test. Following a two-minute recovery, a performance test consisting of 15m sprints was conducted to establish a baseline prior to the first exercise block to provide a maximal performance baseline.

The protocol compromises 16x315s exercise blocks grouped in to 4x21 min blocks. Block 1 and 3 are followed by 4-minute rest with 2 minutes allocated to standing and walking respectively. A 10-minute "halftime" break follows the second block 7 and 3minutes sitting and walking respectively. The test was performed on a full-size Rugby Rubber Crumb 4G pitch. The exercise cycle will require the participant to walk 20m, turn 180◦, cruise 20m and turn 180◦ and jog 10m then perform a ruck (5m carry of a 20kg tackle bag [Gilbert, UK] in 3.5s on which a standardized shoulder height to ensure body height), a scrum (1.5m push of a prowler [Perform Better, UK] with a 70kg additional load in 7s) or a maul (participants compete alternately against each other for 5s to try and gain possession of the ball). They then jogged backwards and repeated the cycle following a standing rest. A 315s block contained five exercise cycles with scrums in cycle 1 and 3, rucks in 2 and 4 and maul in cycle 5, followed by a performance test and 15m sprint. The participants were instructed on how to conduct the test by a pre-recorded CD. The speed of movement was standardized and the participants followed the audio recording to maintain mean speeds for Walking (1.4m/s) , jogging (3.0m/s) and cruising (4.2m/s).

INSERT FIGURE 1 HERE

BURST Performance Test- the performance test is designed to replicate the high intensity bout of rugby union match play combining the effort under load, sprinting and change of direction (figure 2). The test involves the participant passing through a timing gate carrying a tackle bag over 9m, followed by second bag and over the same distance before picking up a ball and sprinting 14m then performing a cutting action and continuing through a final gate to complete. Total time taken between each gate will be recorded. Participants have 25s to then return to the start and perform a max effort 15m sprint (27,28).
To ensure validity of the test the participants were required to wear GPS units (PLAYERTEK Solo KODAPLAY LTD, Ireland) to ensure the distances and speeds covered were like suggested by the burst. The participants were required to give their rate of perceived exertion of the session.

STATISTICAL ANALYSES

Data will be presented as a mean ± SD. A repeated measure ANOVA was used to test the significance of the data. The test was chosen because of the multiple variables and related data as four measures of RSI were taken at different time periods. The groups were divided using the median of the data group and to ensure the data was not violated or corrupt a Mauchly's test of sphericity was conducted set at <.05. The groups were divided in to high and low strength and fitness and relative strength to body mass. All data was analyzed using SPSS for Apple Mac (Version 22). Levene's test of homogeneity was used to test if homogeneity of variance was satisfied (<.05). The tests that showed a significant difference were then compared using an Independent T-Test to compare the groups at each individual measurement.

INSERT FIGURE 2 HERE

RESULTS

INSERT TABLE 1 HERE

INSERT FIGURE 3A HERE INSERT FIGURE 3B HERE

INSERT FIGURE 4A HERE INSERT FIGURE 4B HERE

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INSERT FIGURE 9A HERE INSERT FIGURE 9A HERE

Players were divided in to high and low groups dependant on their testing results. The groups were divided using the median of all results and split to above median for high group and median value and below for the lower group. They were divided in to 30-15 fitness (High:20.4±0.8, Low:18.4±0.9), Absolute Front Squat Strength (High:132.5±13kg, Low:102.5±14.2), Absolute Bench Press Strength (High:122.5±10kg, Low:99.2±12.2), Absolute Prone Row Strength (High:107.1±3.9kg,Low:86.9±25.3), Relative strength (RS) front squat to body mass (BM) (High:139±10%,Low 109±8%), relative bench press to BM (High:125±9%,Low 104±9%) and relative prone row to BM (High:107±12%,Low 91±5%).

There was a statistically significant effect between front squat strength and repeated measures in the RSI. A significant difference between any of the variables tested for absolute front squat strength for RSI (figure 3A). Between subject's effects showed no significant difference between the high and low groups (p=0.589) and no significant difference was visible within subject's effect (p.468) when comparing the groups RSI scores at baseline,24,48 and 72 hours (f=.859). Using a pairwise comparison, the lower group showed a significant difference between baseline and all repeated measures (24hrs p.000, 48hrs p.011, 72hrs p.028) and no significant difference between 48hr and 72hr tests (p=.176). The higher groups showed similar results in having significant differences between baseline and repeated measures (24hr p.000, 48hr p.000, 72hr p.005). The only non-significant difference was between 24 and 48hr tests (p=.055). Front squat strength had a significant effect on CMJ fatigue at 24hrs (p=.001) however there was no interaction between 48hrs (p=.135) and 72hrs (p=.493). CMJ (figure 3B) showed similar results to RSI, with no significant difference shown between the between-subjects effects (p=.441) and no significant difference within subject effects (p=.672, f=.517). The low group showed no significant difference between baseline and repeated tests, there was no significant difference between any of the variables for lower Front squat groups. The higher group showed a significant difference between baseline and 24hrs test (p=.002) and no significant difference between baseline and 48 (p=.321) and 72 hrs tests (p=.394), a significant difference was evident between 24hr and 48hr tests (p.006).

A significant difference was shown for relative strength squat effect on repeated measurements in RSI fatigue. Relative front squat strength to BM showed a significant difference between the high and low subject's groups (p=.014) and a significant difference between the within groups RSI values (p=.011, f=4.083) (figure 4A). A significant difference was shown between the groups at baseline testing (p.013), 24hrs (p=.006) and 72hrs (p=.018) and no significant difference between the 48hrs test (p=.074). CMJ relative strength showed similar results to the absolute strength groups with significance shown at 24hrs only (p=.001). CMJ (figure 4B) showed a significant difference between the high and low groups (p=.029) but no significant difference between within group effects (p=.308, f=1.100). The low RSI front squat group showed a significant difference between baseline and repeated measures (24hr p.000, 48hr p.013, 72hr p.029) the only non-significant difference in the lower RS was between 48 and 72hr tests (p.286). The high relative FS strength group showed a significant difference between baseline RSI and repeated measures (24hr p.000, 48hr p.000, 72hr p.003) the only non-significant difference was between 24 and 48hrs in the higher group (p=.652). Relative FS strength to CMJ performance only showed a significant difference between baseline and 24hrs in both high (p=.035) and low groups (p=.007).

A significant difference was shown between baseline and RSI repeated measures, however in CMJ a significant difference was shown between baseline and 24hrs (p=.001) and not between 48hrs (p=.101) and 72hrs (p=.503) There was no significant difference between the absolute bench press strength high and low groups (figure 5A) RSI scores between groups (p=.824) and within group difference also showing no significant difference (p=.118, f=2.050). CMJ absolute bench press strength (figure 5B) showed similar results to the RSI value with no significant difference between the groups (p=.658) and within the groups effects (p=.823, f=.303). A significant difference for both groups between baseline testing and 24hrs tests was evident low group p=.023 and high group p=.007. There was no significant difference between any of the other measures in respect to their CMJ performance. The lower strength group showed a significant difference in RSI performance in baseline and repeated measurements (24hrs p.000, 48hrs p.005, 72hrs p.027). Lower group showed a significant change in their RSI comparing all measurements except 48hr and 72hr test (p=.085). The higher strength groups showed a significant difference between baseline and all other measures, also significant differences in all comparative results.

A significant difference was shown between the baseline RSI test and repeated measurements at 24,48,72hr tests, only between baseline 24hrs (p=.001) in CMJ. No significant difference was shown between RSI and the relative bench press strength (figure 6A) groups with between subject effect (p=.052) and within group differences (p=.218, f=1.525). Significant changes were found in both groups comparing baseline to repeated tests other than 48 and 72hr (p=.314) in the lower group and 24 and 48hr tests in the stronger groups (p=.177). A significant difference between baseline RSI for the relative strength groups and repeated measures, however CMJ Relative Strength (figure 6B) showed similar results in CMJ (figure 6B) with no significant difference between the groups (p=0.205) and within group (p=.959).

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Prone row indicated a significant difference between baseline RSI and repeated measurements, and CMJ showed a significant result between baseline and 24hrs (p=.001) and no significance between 48hr (p=.072) and 72hrs (p=.180) There was a significant difference between the RSI for the high and low (figure 7A) prone row absolute strength groups (p=.045). There was also a significant difference between the within subject performance (p=.025, f=3.382) for RSI. There was a significant difference between the groups at baseline (p=.010), however no significant difference was shown between the groups at 24hrs (p=.108), 72hrs (p=.094) and 72hrs (p=.059). There was a significant change from baseline to repeated tests for both groups, with no significant difference between 48 and 72 hrs (p=.066) for the lower group and 24 and 48hrs for the higher group (p.135). CMJ results (figure 7B) showed that there was no significant difference between CMJ and prone row strength in regards to between group differences (p=.151) and within group changes (p=.127, f=1.985). Some significant changes between baseline and 24hr in both the lower (p=.016) and higher groups (p.010) and significant difference between the higher groups baseline and 72hr test (p=.040).

Relative prone row strength had a significance chance from baseline to repeated measurements, however CMJ showed significant only at 24hrs compared to baseline (p=.001). No significant difference was shown between groups (p=.671) and within group differences (p=.218, f=1.525) when comparing relative prone row strength to RSI fatigue (figure 8A). Significant change was shown for both groups when comparing baseline to repeated tests. A significant difference between group was shown between CMJ and the relative prone row strength (p.010), however there was no significant difference when assessing within group differences (p=.711). Significant decline was demonstrated for both groups comparing baseline and 24hrs (high p.003, low p.042) also between 24 and 48hr (p=.049) and 24hr and 72hr tests (p=.049) in the higher group.

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RSI performance had a significant effect between the 30-15 fitness groups (figure 9A) (p=.003), however no significant difference was displayed between within the groups (p.224, f=1.504). CMJ showed no significant interaction (p=.400, f=1.000). A significant difference in RSI between was shown between groups at baseline (p=.006) and all repeated measures (24hr p.002, 48hr p.006, 72hrs p.007). CMJ (figure 9B) showed significant difference between groups baseline (p=.024) and 48hrs (p=.025). All results were significantly different in the lower groups, and all expect 24hr and 48hr in the higher groups (p=.459). CMJ results also showed a significant difference between the groups results, and like RSI no significant difference was demonstrated within the groups (p=.400). The lower groups showed a significant difference between the baseline and 24hrs test (p=.015) and no significant difference between other tests. The higher groups had a significant change between baseline and 24hr (p=0.11) and 24hr and 48hr performance (p=0.27).

DISCUSSION

This is one of the first studies to investigate the effects of physiological qualities on recovery ability from rugby union match play. It was evident in all the measurements taken for strength and aerobic capacity that rugby union has a significant effect on neuromuscular fatigue. It was also evident that the stronger strength, relative strength and aerobic capacity performed better generally across all measures. All groups showed statistically significant effects from their baseline test to 24hrs post BURST. This was supported by previous literature suggesting that both codes of rugby had a sizable decline on neuromuscular and musculoskeletal markers (16,20,21,25,33,40). Research in rugby league has indicated that neuromuscular fatigue has recovered 48hrs after rugby (10), the findings of this study did not demonstrate full recovery in that time frame and suggests that recovery could take up to 72hrs.

Relative front squat strength to body mass showed to be significantly different between the groups, and within the group RSI measures. The higher group recorded significantly higher RSI scores in baseline, 24hr, 72hr tests compared to their counterparts. The relatively stronger front squat group also had significantly better CMJ performance compared to the lower group however no difference was reported between each group and their repeated measurements. These findings were supported by McLellan, Lovell and Gas (2011i), who found that lower body strength and power had a meaningful change when measuring NMF post-match, and found that normality was restored at 48-72hrs which is consistent with this study. The results of this research were further supported by Gabbett (2016) and Suchomel, Nimphius and Stone (2016) who found that LB strength and power had a significant effect on ability to reproduce high levels of skills under fatigue, and power output repeatability. In contrary to these studies, absolute lower body strength values had no effect on the group's ability to recover.

There was a significant difference between the higher fitness groups for both CMJ and RSI when assessing their baseline tests and all repeated measurements. The RSI performance was significantly different for both groups; however, their recovery rate was similar. The CMJ performance recovered better in the lower 30-15 test group, however the higher groups performed better in both RSI and CMJ tests overall. These results were consistent with Gabbett's (2016) findings that higher aerobic capacity qualities allow better highly neural exercise performance. Interestingly Johnston et al (2015) found that players with better aerobic capacity could cover more distance and game-play load than their lower capacity counterparts and recovered quicker post-match play.

Interestingly there was a substantial difference between RSI performance for the prone row strength groups, but not when assessing their CMJ repeated performance, but there was significance between the CMJ relative strength and not the RSI. Gabbett's (2016) study found that pulling strength had no significant difference between UB pulling strength and rugby performance, however they used a chin up measurement, which is not directly correlated with prone row. This is in-consistent with previous research that has indicated that UB strength has no significant effect on NMF and LB power performance, however the literature using prone row as a measurement is lacking. Research was consistent with other findings of this study that found that bench press strength and relative strength to body mass has no effect on NMF after induced rugby fatigue, this could be since there is a significant body of research supporting the effect and fatigue rugby causes on the lower extremities (10,14,25,29,40).

There is substantial evidence to suggest that rugby union induces a significant amount of neuromuscular fatigue and is well established in literature. The purpose of this study was to investigate what physiological qualities influence athlete's ability to recover post-match, to widen understanding the physical requirements needed to compete from week to week and how it can influence training periodization. The findings of the study suggested that good levels relative lower limb strength, upper body pulling strength and aerobic conditioning made a difference in recovery. Rugby union literature is strong in supporting the effect of NMF and how to monitor, but not specifically in what physical qualities help improvement.

The conclusion of this study was alike the findings were like that of rugby league research suggesting that high fitness measures and squat performance allowed athletes to recover quickest these findings were consistent in this study, suggesting that post match NMF is lower in athletes with more developed aerobic conditioning and relative strength. The results of the study showed that athletes who had greater physical qualities had significantly higher ability to produce power with RSI and CMJ and that relative strength to BW was a key indicator (14).

Interestingly there was a significant interaction between the RSI and all repeated measures in most groups, and only between baseline and 24hrs in CMJ testing. Both tests have proven reliability in testing NMF, however the results of the study have differed in detecting fatigue. This could be due to the difference in SSC elements of the jump protocol and different kinetic and kinematics of the DJ and CMJ (18). Roe et al (2016) and Clarke et al (2015) found that CMJ was a reliable way to test for between day measures of fatigue and had proven sensitivity in fatigue management of rugby players. Oliver, Lloyd & Witney (2015) tested in-season peripheral and neurological measurements in season in a similar cohort to this study. They found RSI, LB stiffness and CMJ to be effective measurement tools but displaying different results, as found in this study. They suggested that CMJ was sensitive in testing both short and long term fatigue and stiffness better for longer term fatigue.

The higher groups neuromuscular performance was far superior to the lower groups across fitness, relative lower body strength, absolute prone row strength, and slightly higher than the lower group in other tested measures. This was supported by literature that found similar results, that with increased physical markers post-match fatigue neuromuscular fatigue was reduced. They also found that the subjects with better physical test scores covered more distance and had more a influence during the game, so they worked harder and recovered quicker. Particularly leg strength and fitness, through improving these metrics it has been found that the ability to reproduce high intensity efforts in-play have improved (14, 35).

However, for future research prospective would be useful to conduct a similar study around actual match play and not a simulation. Even though the BURST has been validated and deemed reliable in inducing rugby match play demands, the physical contact demands place a significant demand on ability to recover as suggested by Roe et al (2017). They suggest that all fatigue markers measured were effected by including contact in to the session. For this study the BURST was appropriate to quantify the demand and expose the players to a reliable level of activity that is unachievable through a rugby match due to the different positional demands.

PRACTICAL APPLICATION

- Relative leg strength, bench pull and fitness had made a significant difference to recovery ability.
- The 'higher' groups had significantly better results in most of the testing measures, and the higher groups recovered quicker than lower groups. Providing evidence of the importance of physical qualities in performance which is heavily supported by research, but also ability to recover from NMF.
- Where there was a significant difference in the recovery ability, the groups had a significant difference in DJ and CMJ performance.

- The findings of the CMJ results may be useful when programming for in-season rugby athlete from a high neural load prospective. Understanding the match play demand is important, and this study demonstrates the influence of NMF on 24,48,72hrs. This study suggests that at 48-72hrs athletes should be recovered from NMF.
- The study would suggest avoiding a 'high neurological day' 24hrs-48hrs post-match, avoiding such activities such as heavy strength training and power. Also, considering the high demand of the sport, it could also support influencing the rugby training session design avoiding full contact training, high intensity units and attack plays (that include HSR) 24hrs post-match.

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LIST OF FIGURES

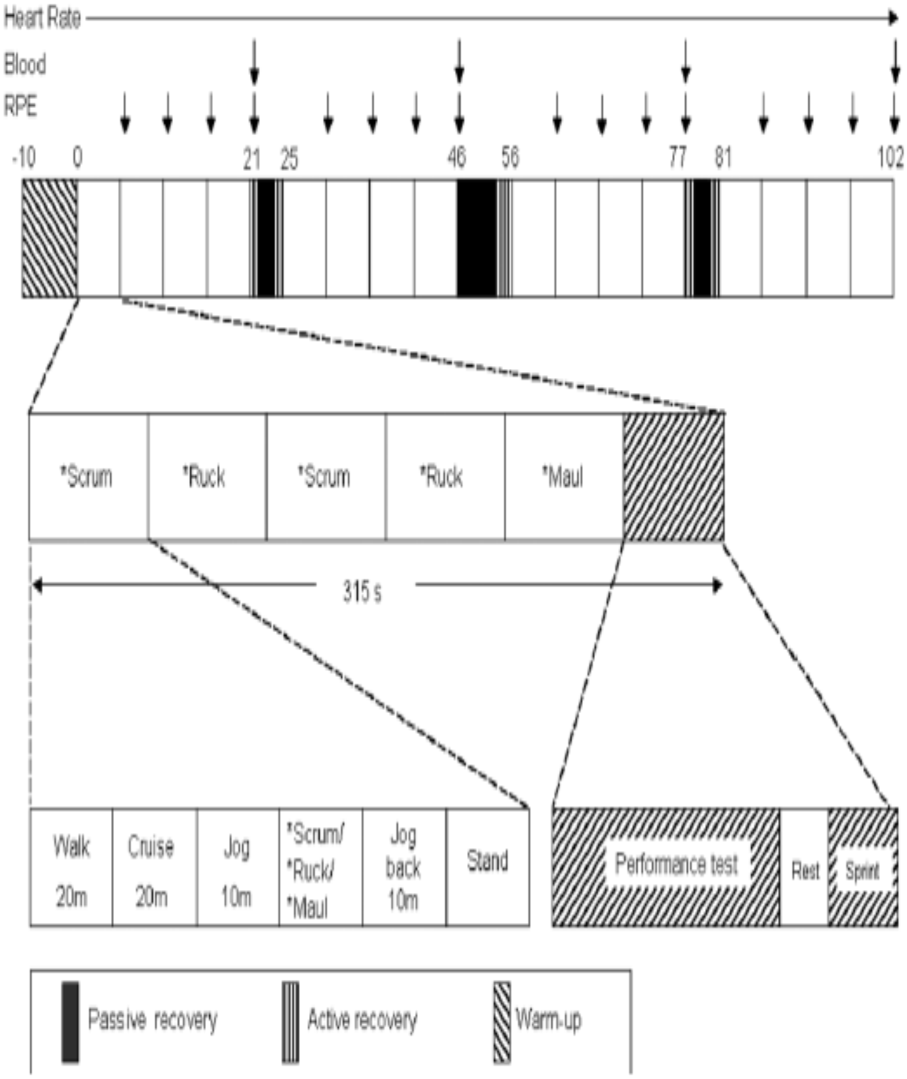


Figure 1- the exercise cycle protocol of the BURST (27,28).

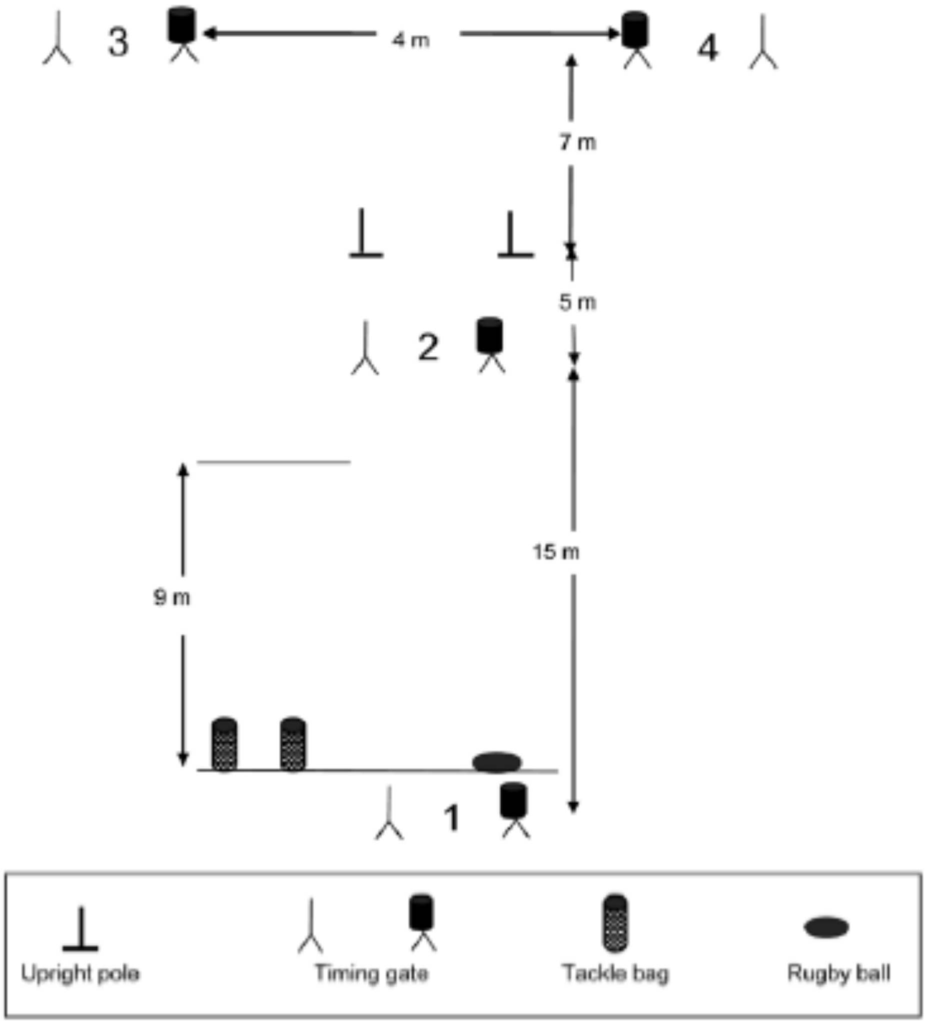
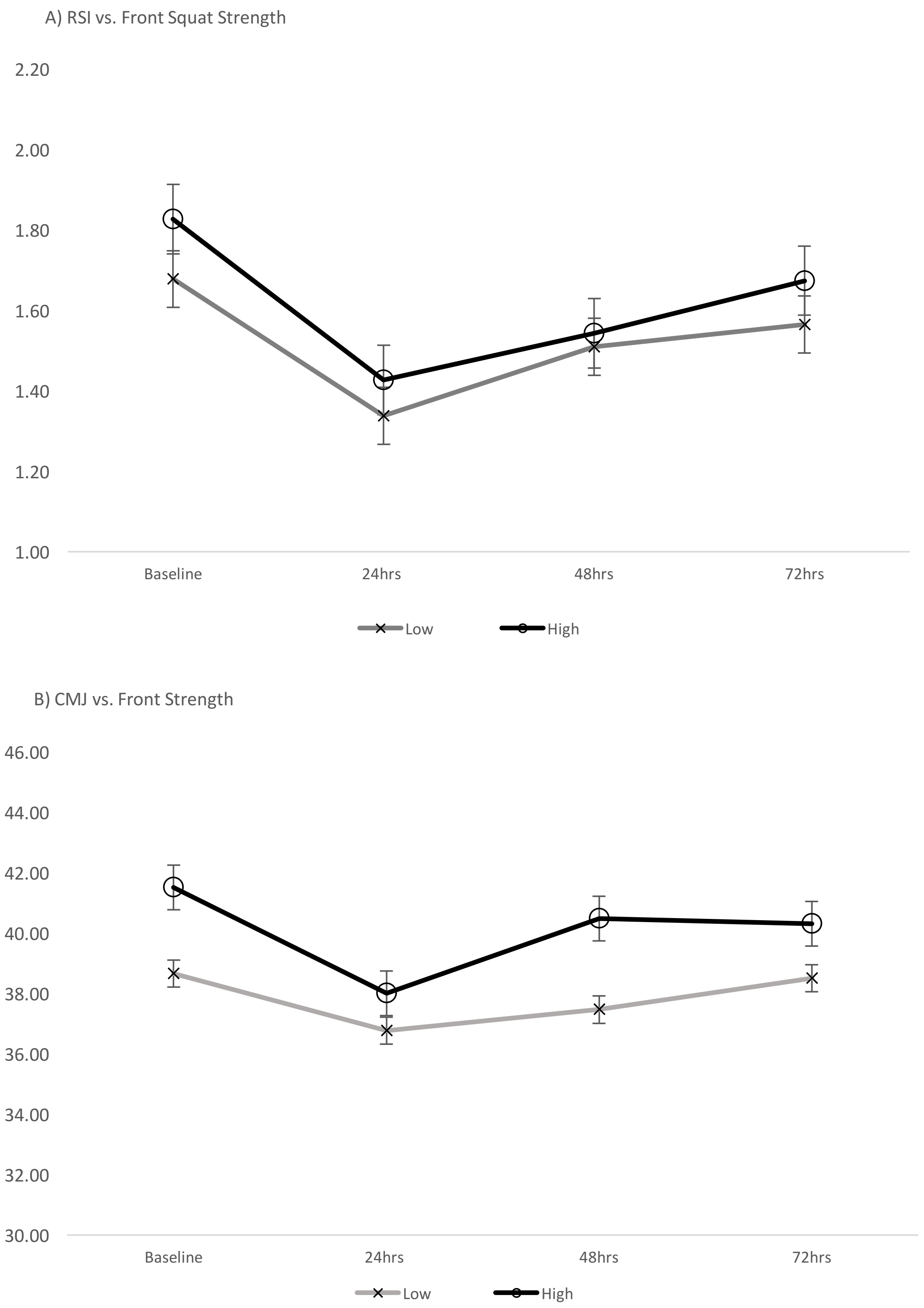


Figure 2- The BURST Performance Test

Figure 3. Mean comparison of high and low groups vs A) RSI values and B) CMJ at baseline, 24,48 and 72hrs intervals for front squat absolute strength.



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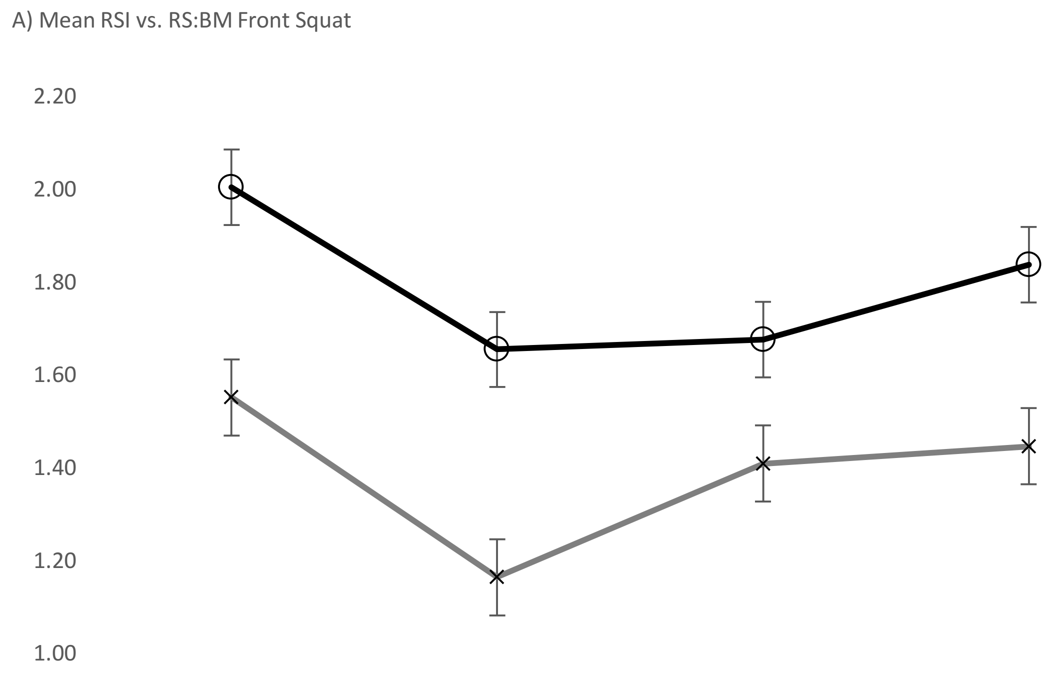

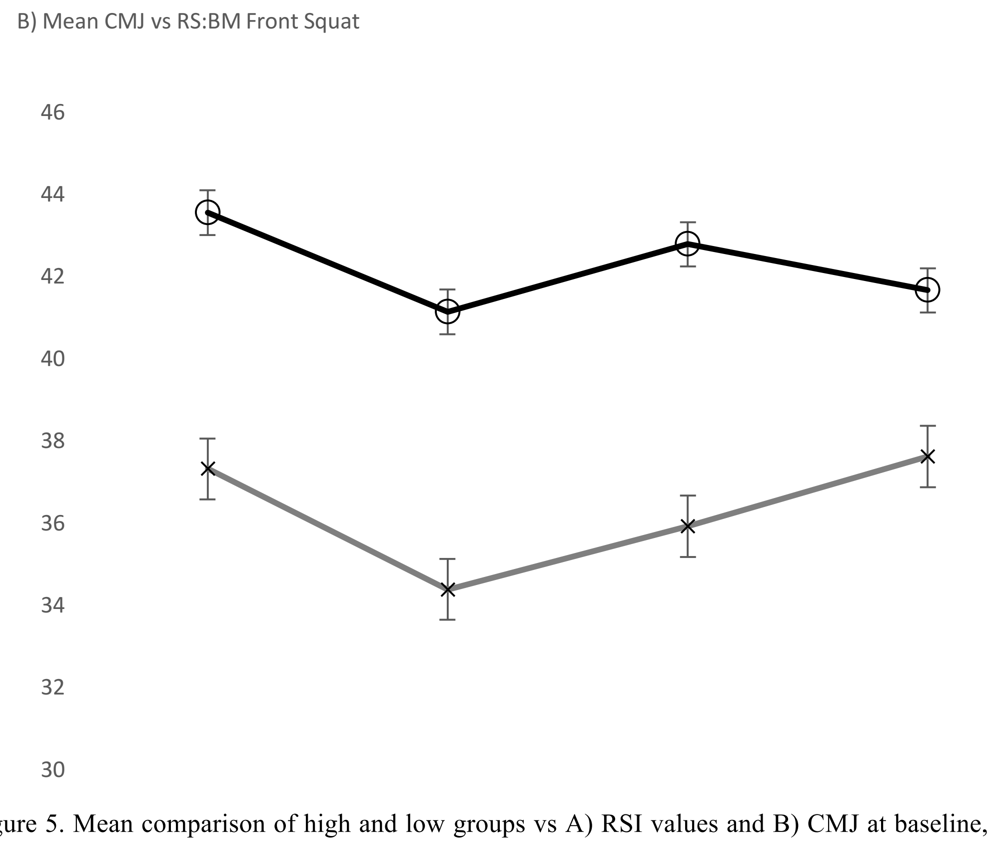

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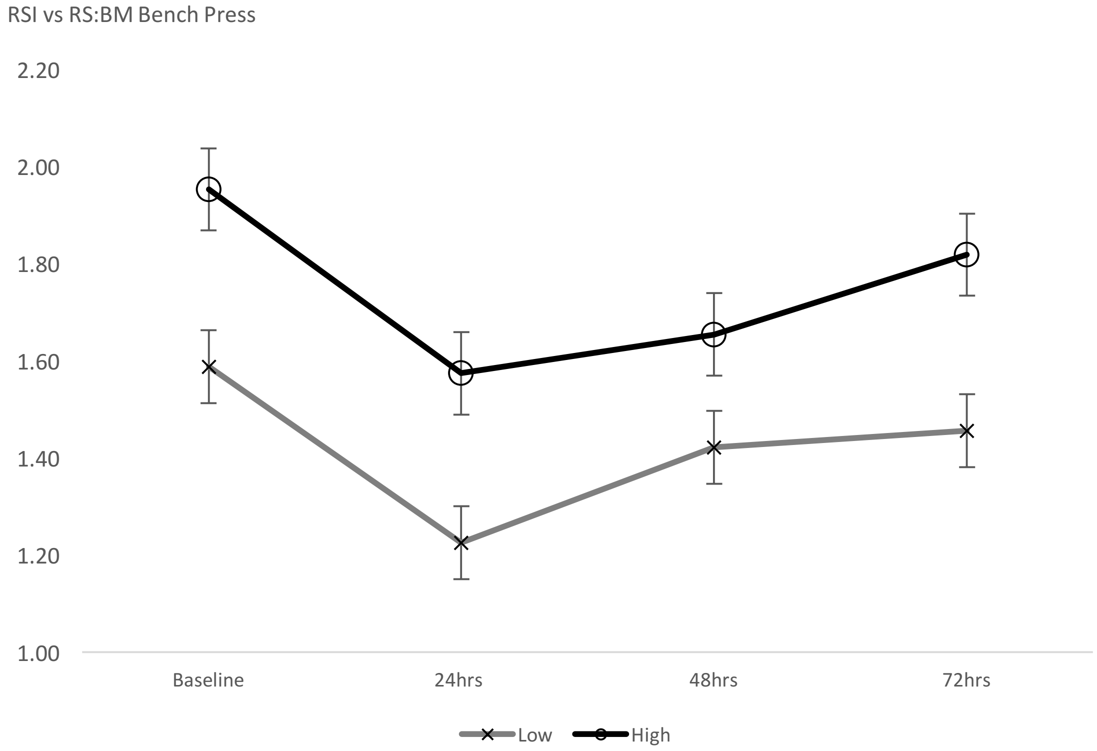


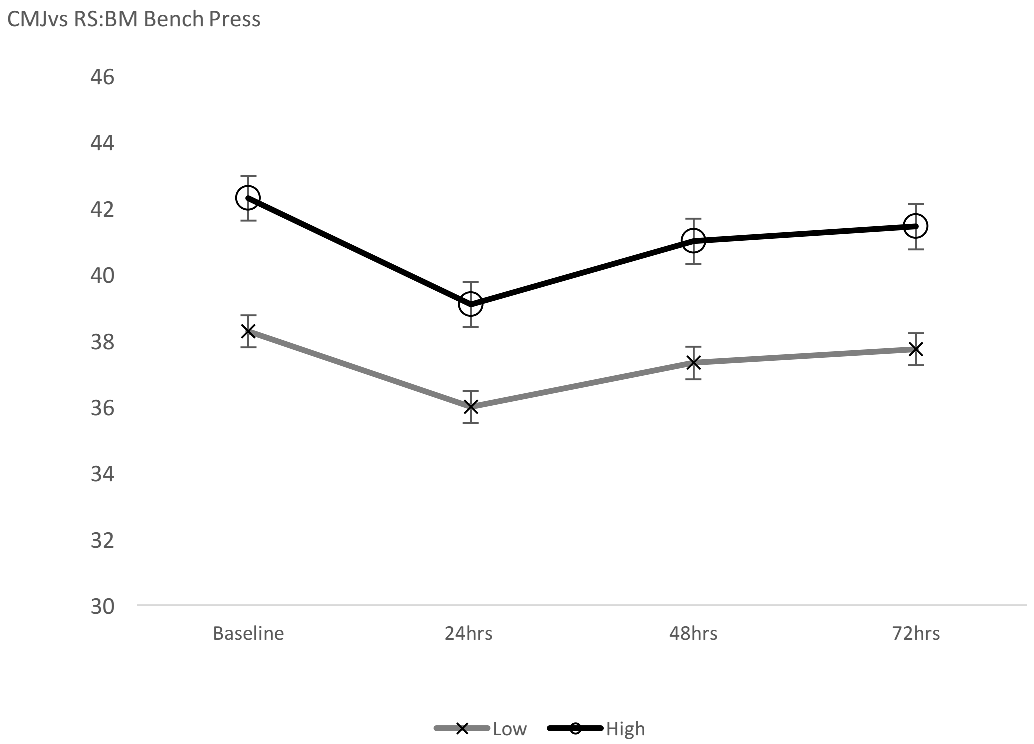
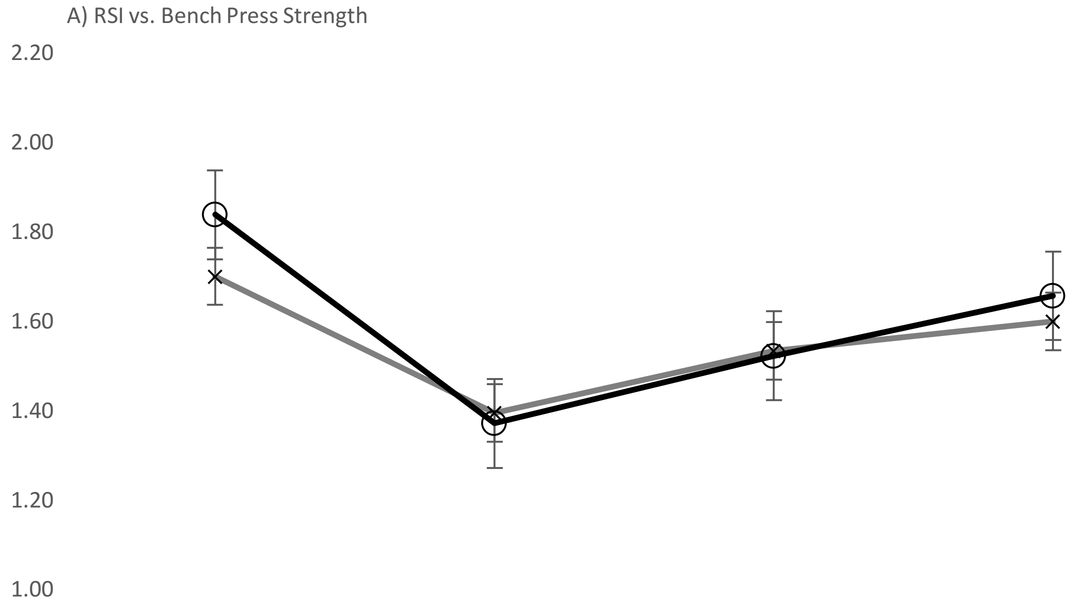


Figure 6. Mean comparison of high and low groups vs A) RSI values and B) CMJ at baseline, 24,48 and 72hrs intervals for relative to body mass bench press strength.



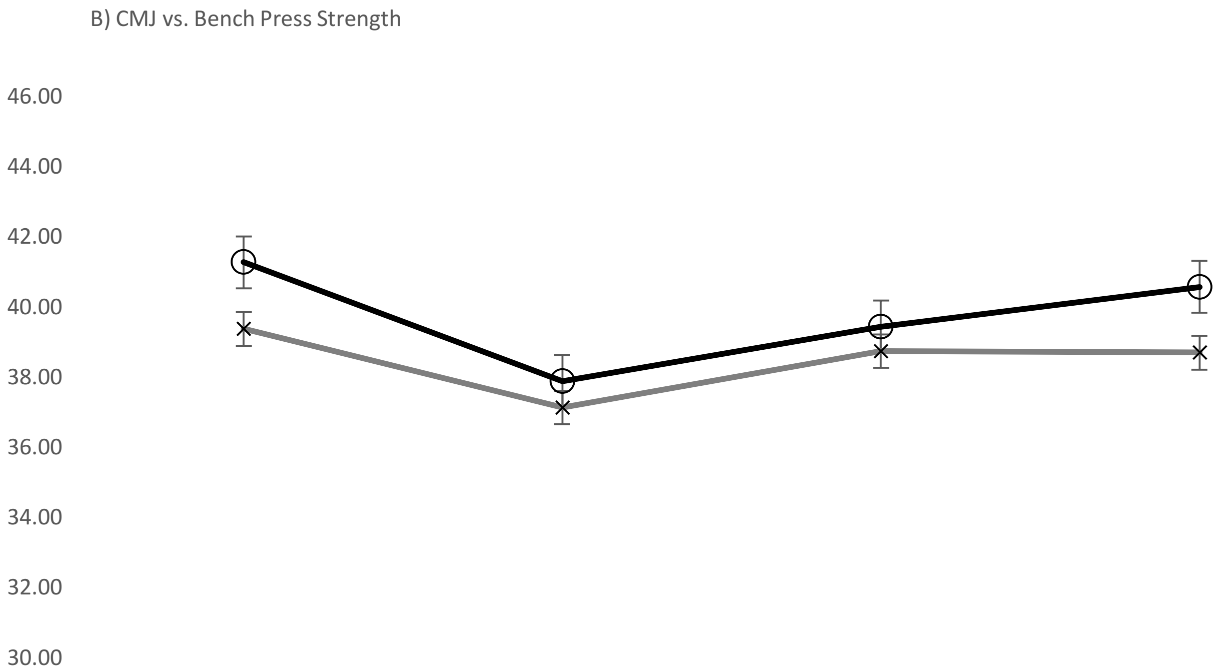
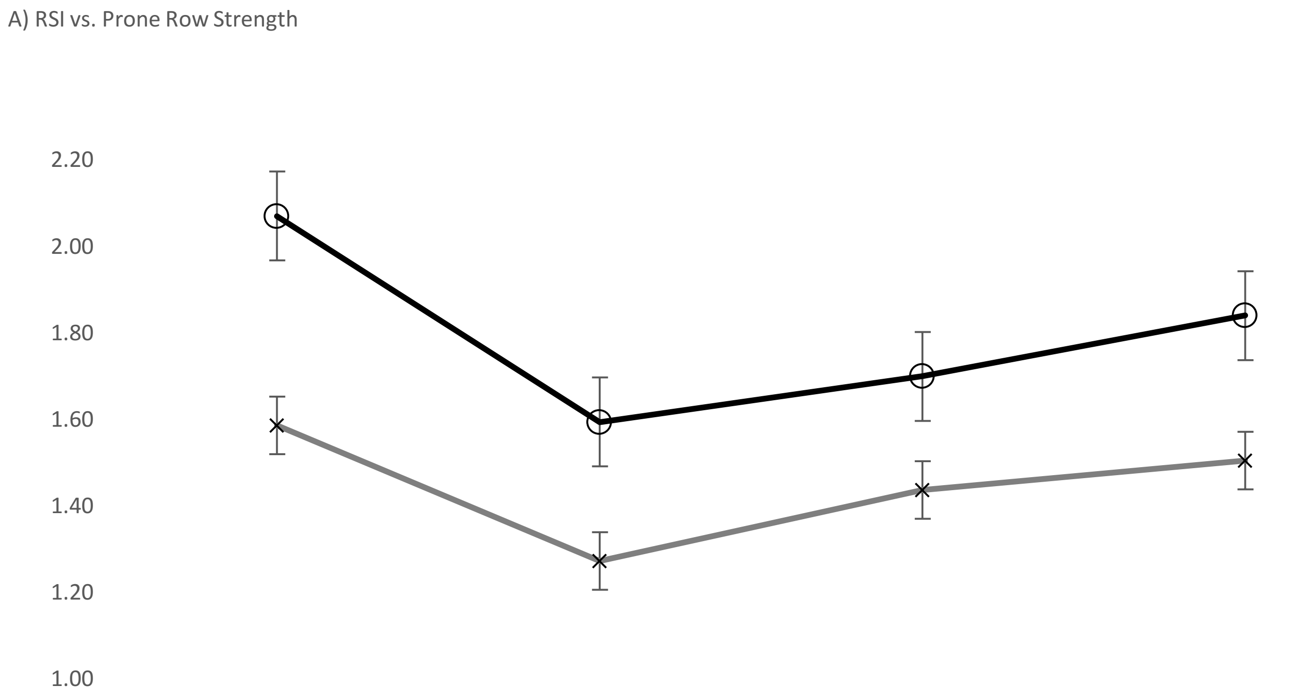


Figure 7. Mean comparison of high and low groups vs A) RSI values and B) CMJ at baseline, 24,48 and 72hrs intervals for Prone row absolute strength.



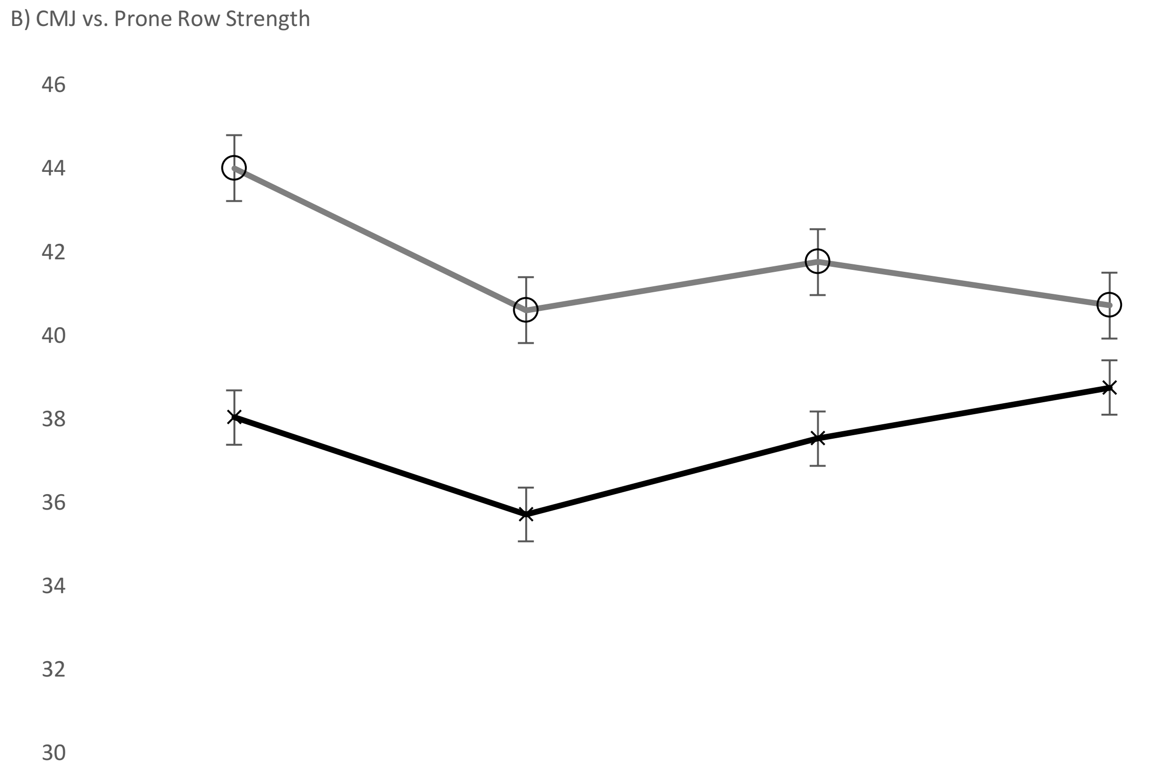


Figure 8. Mean comparison of high and low groups vs A) RSI values and B) CMJ at baseline, 24,48 and 72hrs intervals for relative to body mass prone row strength

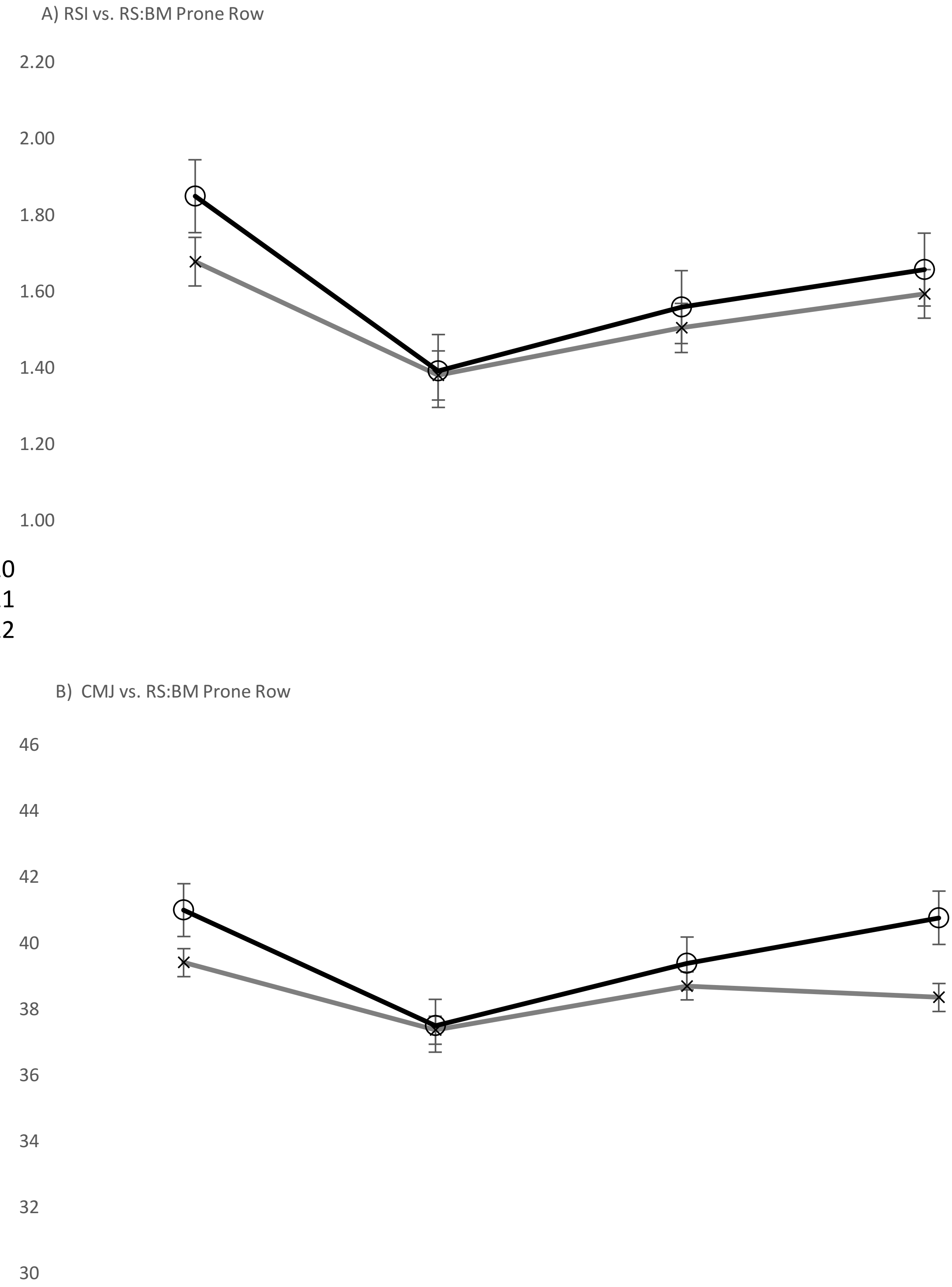
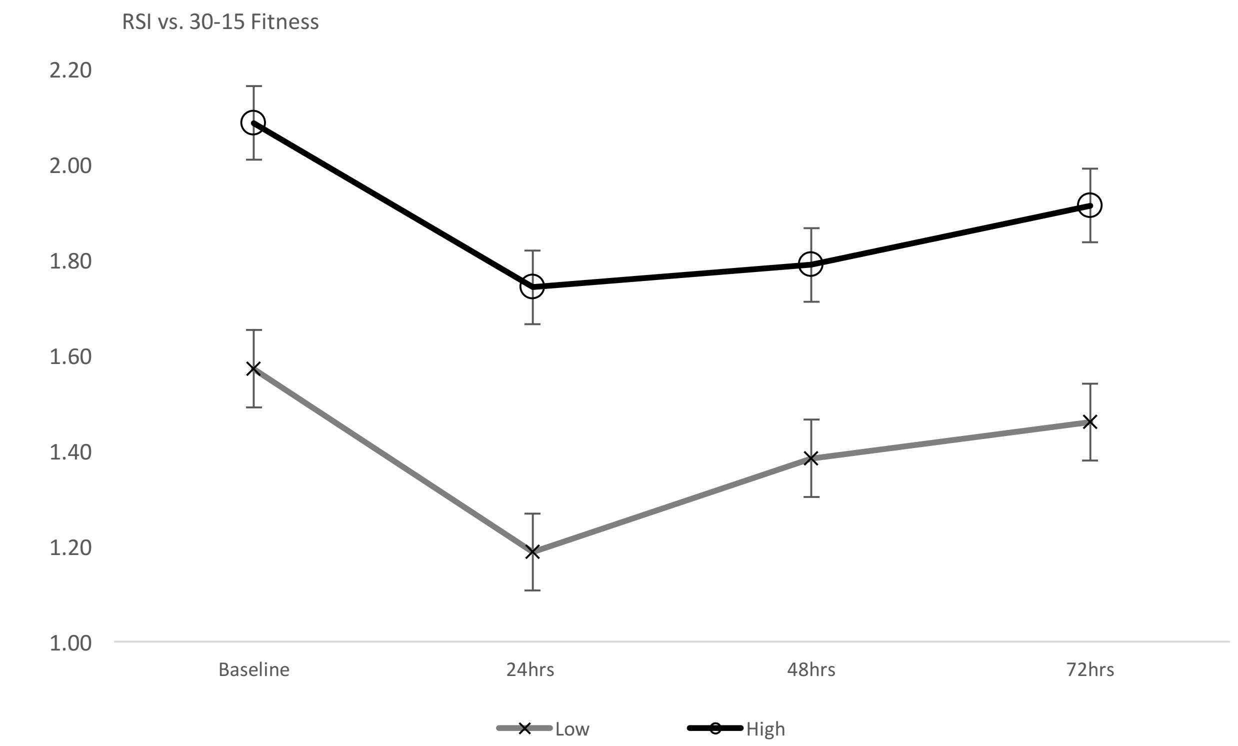
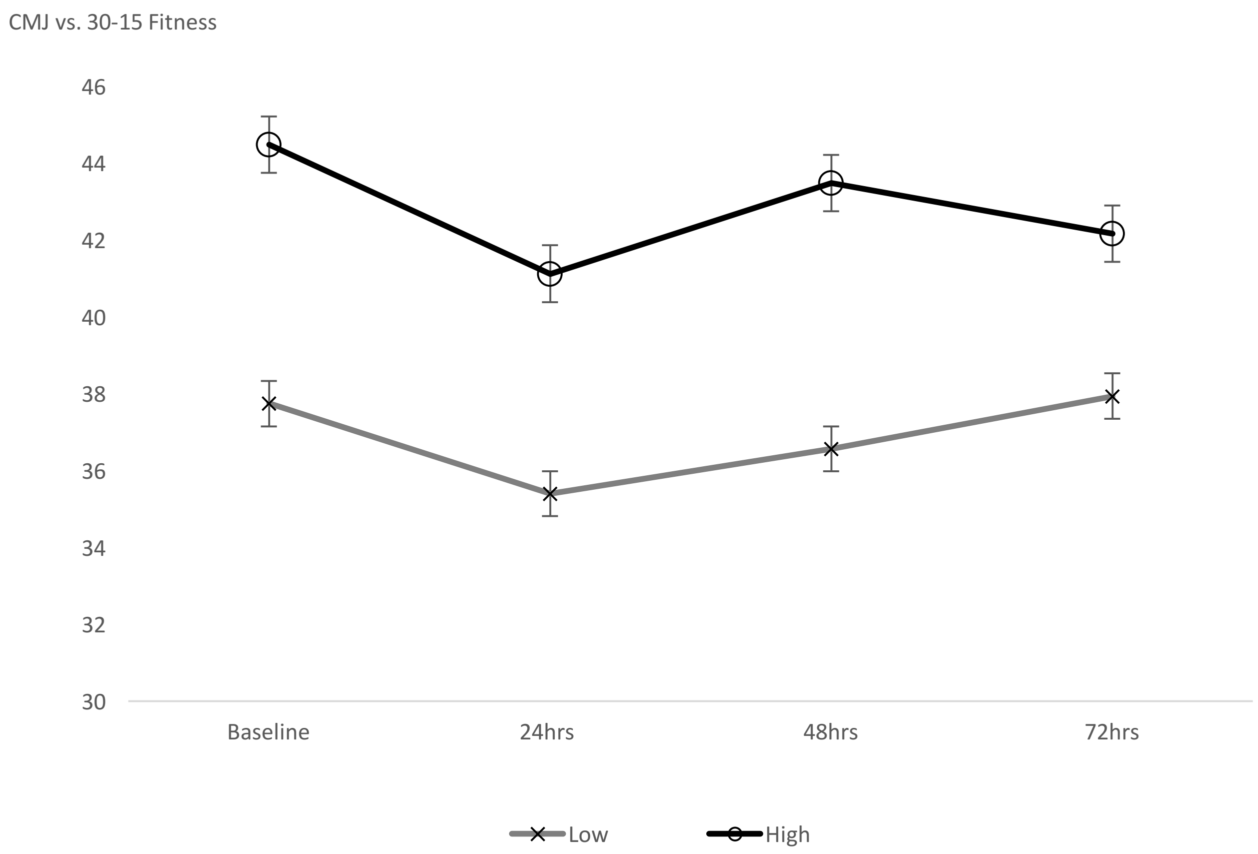


Figure 9. Mean comparison of high and low groups vs A) RSI values and B) CMJ at baseline, 24,48 and 72hrs intervals for 30-15 fitness test.


RSI vs. 30-15 Fitness
2.20
2.00
1.80
1.60
1.40
1.20
1.00
Baseline
24hrs
48hrs
72hrs
Low
High


CMJ vs. 30-15 Fitness
46
44
42
40
38
36
34
32
30
Baseline
24hrs
48hrs
72hrs
Low
High

TABLES

	15m Sprint	Total Distance(m)	HSR m (>5m/s)	RPE
Mean, Std Dev	2.80±0.13	7345±1084	857.4±296.4	7.7±0.9
BURST (Roberts et al.2010)	2.69±0.13	7078	662	n/a

Table 1- Quantifying the BURST incomparision to Roberts et al 2010