How does mental and physical fatigue affect a rugby player’s force production during scrummaging?

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Abstract:
Aims: This study investigates the effects of physical fatigue, mental fatigue and their combinations on the ability of rugby players to produce force during rugby scrummaging.

Method: 10 male subjects (Mean age = 27.4 ± 3.92, Weight =102.9kg ± 10.96) were recruited from local rugby union football clubs in the Stockholm area. Scrummaging force measurements were collected following and before treatments (control), after a 30-min mental task and after a physical fatigue protocol. The mean peak force was calculated by averaging the force data 1 second around the highest peak of force during a 5 second sustained push.

Results: Mean force decreased significantly after the physical fatigue (PF) protocol compared to the control (CON) (PF = 1740 ± 342 N vs. CON = 2007.5 ± 359 N. P= 0.0009) and combinations of physical and mental fatigue (PMF) or mental and physical fatigue (MPF) were also found to significantly decrease compared to the control (PMF = 1750 ± 348N vs. CON = 2007.5 ± 359N. P=0.0014 and MPF = 1818 ± 335N vs. CON = 2007.5 ± 359N. P=0.026). Mental fatigue did not significantly decrease mean peak force during the sustained push of a rugby scrum (MF = 1912 ± 321N vs. CON = 2007.5 ± 359N. P=0.52).

Conclusion: Physical fatigue reduces the ability of rugby players to produce force during rugby scrummaging, however mental fatigue does not. Furthermore, mental fatigue does not exacerbate the effects of physical fatigue on scrummaging performance.
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1 Introduction

1.2 What is a Scrum?

In Rugby Union, the scrum is an explosive event that requires eight players from each team to bind together in standardized manner as instructed by the International Rugby Board (2016). Each pack of eight players binds together and then awaits the referee’s instructions to engage with the opposite pack in order to compete for possession of the ball that is thrown into the scrum by a player playing the scrumhalf position. Maximal force production is required by the participating players in order to effectively compete for the ball as both teams aggressively push against each other in an effort to gain or retain territory and increase their chances of successfully acquiring the ball.

Traditionally the scrum has been used to restart play following a minor infringement in the game. However, in the race for a competitive edge in the modern era of rugby, scrumming has become recognized as a powerful skill (Milburn, 1986), both offensively (e.g. exhausting the opposite team and providing a strong platform for an attack by the ‘backs’) and defensively (e.g. keeping the ball away from the opposition whilst reducing the remaining game time and subsequently limiting your opponent’s chances of a successful counter-offensive.)

1.3 Is it affected by mental and physical fatigue?

At the time of writing this paper, very few studies have attempted to investigate whether mental fatigue develops in rugby players during the course of a match. One such study that has investigated this phenomenon is by Mashiko, et al. (2004). Their study involved the use of biochemical analysis (blood glucose, total protein, albumin, triglyceride, free fatty acid, total cholesterol, high density lipoprotein cholesterol, glutamate oxaloacetic transaminase (GOT), lactate dehydrogenase (LDH) and creatine kinase (CK). As well as psychometric data using the profile of mood states (POMS) questionnaire in order to observe changes in mental or physical fatigue on 37 rugby players, playing at a high level, following a match. Their results found significant increases in both biochemical measures of physical fatigue (increased serum levels of FFA and intramuscular levels of LDH, GOT and CK) as well as in the subscales relating to mental fatigue within the POMS questionnaire (Depression, Fatigue, Vigour and total mood disturbance) following a rugby match. These results offer exploratory evidence
that rugby players do experience both mental and physical fatigue during a match. Grubbelaar (2012) also followed a similar pre/post match protocol on rugby players, using the Stellenbosch Mood Scale (STEMS) in lieu of the POMS questionnaire, on a sample of 31 rugby players from a South African university. Interestingly, these results also found differences in mood depending on whether a team won or lost. Players in teams that lost tended to report increases in tension, anger and confusion, whereas feelings of tension were reported to have decreased significantly in teams that won matches. Moreover, irrespective of the outcome of the matches, players experienced increases in anger, fatigue and a depressed mood following a match, and scores for vigour decreased.

Whilst these studies offer encouraging evidence that rugby do players experience both mental and physical over the course of a match. Walsh (2014) also goes on to suggest that team sports tend to place greater stress on brain, compared to individual sports e.g. athletics, swimming, etc. This is supported by research in other team sports, such as football (Smith, et al, 2016; Smith, Marcora & Coutts, 2015). The increase in cognitive demand placed upon players in team sports may subsequently contribute towards the onset of mental fatigue. In rugby, these demands may involve continuous:

- Error monitoring (e.g. awareness of handling errors and over commitment of players at breakdowns).
- Response inhibition (e.g. correctly identifying and successfully countering 'dummy' passes)
- Sustained attention and vigilance (e.g. awareness of player positions and movement of the ball on the pitch)
- Quick decision-making (e.g. deciding whether to ruck, maul, drive a scrum, defending the 'blindside' of a breakdown.)

1.4 The current body of research on the effects of physical fatigue and performance.

It is well known that physical fatigue reduces a muscles ability to generate maximum force during contractions. Indeed, Physical a fatigue may be defined as a reduction in maximal force exerted by a muscle due to alterations of peripheral and central mechanisms (Enoka & Stuart, 1992). Several studies have subsequently attributed reductions in performance (e.g. total running distance, total high intensity running distances, etc.) to the onset of physical fatigue in players. Coutts, et al. (2010) found that Australian Rules Football Players, a game
that shares many similarities to rugby union, reduced their total running distance and total high intensity running distance during the second half/quarter of a match. Sirotic, et al. (2009) reported similar findings in their study that compared the match demands of elite and semi-elite rugby league players. Their results found that total running distance of elite rugby players tended to decrease in the second half of the game and was, again, attributed to the onset of physical fatigue. Davies & White (1981) also found that maximal twitch and tetanic tensions of the m. triceps surae were markedly reduced following one hour of box stepping with a constant leg lead. A similar reduction in m. quadriceps strength was also found by Newham et al (1983) following a fatiguing leg test. More recently, a study performed at the University of Wales, Bangor (Byrne & Eston, 2002) found that isometric, concentric and eccentric leg strength i.e. knee flexion decreased immediately following a protocol that consisted of 100 repetitions of a barbell squat performed in 10 sets of 10 repetitions with a load equivalent to 70% of the participant’s body-weight. Interestingly the main effect of this protocol reduced force outputs by 20%, one hour and took several hours, to days, to recover (Byrne & Eston, 2002).

Together, these studies provide strong evidence that:

a) Rugby players do experience physical fatigue during a match.

b) Physical fatigue does have a detrimental effect on their ability to perform maximal voluntary contractions.

1.5 The current body of research on the effects of mental fatigue and performance.

Despite an early scientific observation reported by Mosso (1891) in which muscular endurance of the index finger was reduced following long lectures and examinations. Mental fatigue and its effects on physical performance have received little attention until the beginning of the 21st century. One of the first studies published, in the modern era, was by Marcora et al (2009) and found that mental fatigue was strongly associated with an increased perception of effort and a subsequent decrease in aerobic performance. Cyclists significantly decreased their time to exhaustion whilst cycling at 80% of their calculated peak power, following 90 minutes of a mentally fatiguing task (AX-continuous performance task). These results were also, later, supported by (Smith, Marcora & Coutts, 2015). Using the same 90-minute mentally fatiguing task (AX-CPT), they investigated the effects of mental fatigue on intermittent running performance. Results showed that participants decreased the velocity of their low intensity activity but their high intensity activity velocity, as well as their peak
velocity were unaffected by the mentally fatiguing task. These results may be particularly significant for our study, as high intensity activities and the attainment of peak running velocities typically require a high degree of anaerobic muscle activity that it is not dissimilar to the demands of maximal voluntary contractions during rugby scrummaging. Although Smith, Marcora & Coutts (2015) study is not without limitations, the lack of change of velocity during high intensity activity may also be explained by the increased time for recovery due to the decrease in velocity during low intensity activity.

Furthermore, the consensus on mental fatigue and its effects on anaerobic performance are not unanimous. Bray et al. (2012) found a significant reduction in intermittent handgrip MVCs of participants, interspersed by 3 minute bouts of mentally fatiguing tasks (incongruent stroop task) for a total of 22 minutes. Suggesting a possible interaction between mental fatigue and maximal force production. Dorris et al. (2012) also found that a mentally fatiguing task reduced the number of sit-ups completed by rugby and hockey players and suggested ‘ego-depletion’ as a possible mechanism. Whilst the authors proposed a psychological mechanism to explain the reduction of sit-ups performed, components of the ’ego-depleting’ task shared many similarities to other mentally fatiguing tasks e.g. the Stroop-word task as both require error monitoring and sustained self regulation (Muraven and Baumeister, 2000). Bray, et al. (2012) proposed that the decrease in MVCs following the mentally fatiguing task was caused by alterations in a central mechanism i.e. a reduction in central nervous systems abilities to transmit motor stimuli.

However, there are several limitations to the studies of Bray et al (2012) and Dorris et al (2012). Differences found in Bray et al. (2012) may be explained by a reduction in motivation exacerbated by the mental fatigue task, as well as the early onset of peripheral fatigue induced caused by increased activation of shoulder muscles during mentally fatiguing tasks (Mehta & Agnew, 2002). It is for this reason, that a measure of motivation has been incorporated into the methodology of this study. Furthermore, peripheral fatigue of the trapezius and forearm muscles may also develop, due to use of these muscles if the participant is required to hold the paper-version Stroop-word task (i.e. printed on cards) or through repetitive mouse or keyboard movements during the computer-version Stroop-word task.

Furthermore, Bray et al.’s (2012) proposal that alterations in central mechanisms may explain the reduced MVCs in their study has largely been refuted by later studies (Rozand et al. 2014; Pageaux et al. 2013). Both these studies found no evidence that mental fatigue alters muscle activation during MVCs of the knee extensor muscles as no difference was found between MVCs and transcutaneous, electrically evoked contractions of
the knee extensor muscles following mentally fatiguing tasks (incongruent stroop task) and an emotionally neutral control task. Furthermore, Martin et al. (2015) found that 90 minutes of a mentally fatiguing task (AX-CPT) did not affect measures of isometric leg extension, countermovement jump and 3-min all out cycling in their subjects.

The current body of research regarding mental fatigue and anaerobic performance, allows us to assume that:

a) Mental fatigue does not reduce central drive to the muscles.

However, it remains unclear whether mental fatigue does have some effect on anaerobic performance.

**1.6 Mechanisms of physical fatigue.**

Physical fatigue may be defined as a reduction in the muscles ability to generate a maximal voluntary contraction (Bigland-Ritchie & Woods, 1984) and is the result of both peripheral changes i.e. mechanisms that occur at or distal to the neuromuscular junction and central alterations i.e. mechanisms that occur proximal to the neuromuscular junction. However, during short-bouts of exercise, dysfunction of peripheral processes may be the primary cause of physical fatigue (i.e. due to metabolic changes and/or muscular damage) rather than alterations in central drive towards the muscles (Lepers et al., 2000; Millet & Lepers, 2004; Skof & Strojnik, 2006).

Physical fatigue may vary depending on the characteristics of the activity performed and therefore the variation in fatiguing mechanisms (Finsterer, 2012). Causes of peripheral fatigue involve the build up of metabolic by-products due to increased consumption, decreased synthesis and/or reduced stores of energy. These metabolic changes may be reflected by increased levels of serum lactate, ammonia and oxipurines. Furthermore, oxidative stress caused by increased production of reactive oxygen species (ROS) during intense exercise have also been linked to contractile dysfunction and muscle atrophy, which both promotes muscle weakness and fatigue (Vollaard, Sheerman & Cooper, 2005; Reid, 2008.) However, the precise mechanisms of how it causes contractile dysfunction remain unclear (Steinbacher & Eckl, 2015.).

Furthermore, Muscle damage can also cause a reduction in strength due to damage to contractile filaments of muscles. This phenomenon is not to be confused with muscle fatigue as muscle fatigue can recover relatively quickly (minutes to hours) and does not entail damage to myofibrils, whereas muscle damage can take several days to recover.
1.7 Mechanisms of mental fatigue.

Whilst the exact neurobiological mechanisms of mental fatigue are complex and not fully understood, some studies have shown that mental fatigue is associated with increased activity of the anterior cingulate cortex (ACC) (Cook et al, 2007; Lorist et al, 2005). Several studies have reported that increased activation of the ACC may subsequently be associated with perceptions of effort (Williamson, Fidel & Mitchell, 2006; Williamson et al, 2001; Williamson et al; 2002) has provided a psychobiological rationale for the effects of mental fatigue on endurance performance in previous studies (Marcora, et al. 2009). Whilst this is an interesting proposal for a neurobiological mechanism of mental fatigue, it likely represents a small part of an otherwise complex mechanism. Subsequently, caution should be taken when speculating that it is a primary contributing mechanism. Nonetheless, this psychobiological rationale does help to support a more tangible mechanism of mental fatigue that could impair anaerobic abilities. That is that increased perceptions of exertion, brought about via increased activity of the ACC, may subsequently have a detrimental effect on motivation and effort towards a task. Shigihara et al (2013) proposed that voluntary activity was positively related to mental effort, which is subsequently a controlled by motivation and perceived effort via sensory, motor and cognitive systems. Conversely voluntary activity is negatively related to increases in the ‘inhibitory system’ e.g. mental fatigue and reductions in motivation. According to this conceptual hypothesis an increase in activity of the ‘inhibitory system’ via mental fatigue, should negatively affect an individual’s voluntary activity and subsequent task performance. This theory is compatible with Marcora et al (2009) proposal that the effects mental fatigue may limit an individual’s tolerance of exercise independent of cardiorespiratory and musculoenergetic alterations.

Theoretically, this may also influence a person’s motivation towards a task. For example, within the framework of self-determination theory (Deci & Ryan, 1985), an increase in perceived difficulty/exertion towards a task, may be explained as a threat to competence (one of the central components that facilitates intrinsic motivation towards a task). In other words, if a person feels that a task is too difficult due to fatigue, they may feel less competent to successfully complete the task and withdraw effort.

An increase in perceived exertion could also lend itself to other psychological frameworks of motivation such as Achievement Goal Theory (Nicholls, 1984), as individuals that are performance orientated and perceive a task being ‘too difficult’ e.g. due to an
increased sense of perceived exertion may avoid the task in order to protect their ego. For example, a rugby player that perceives a scrum as too difficult may underperform and attribute the failure to a lack of will, rather than a lack of physical ability in order to save face.

Figure 1. A visual representation of Shigihara's conceptual hypothesis

1.8 Could a combination of fatigue conditions have greater effects than a single type of fatigue?

Despite evidence that rugby players do experience both physical and mental fatigue during matches, no research to date has attempted to investigate the combined effects of mental and physical fatigue on anaerobic performance. Nor has a study attempted to investigate the effects of mental fatigue only on force production during scrummaging.

It is possible that mental fatigue will induce alterations in psychological and neurological processes that may exacerbate the well-known detrimental effects of physical fatigue a person’s ability to perform a maximal voluntary contraction alone.

1.9.2 Aim and hypotheses of this study.

The aim of this thesis is to investigate the individual effects of physical and mental fatigue, as well the combination of these conditions on the force producing abilities of rugby players during a rugby scrum.

The hypotheses of this study are:

• The mental fatigue condition will produce lower maximal force values than the control.
• The physical fatigue condition will produce lower maximal force values than the control.
• The combination of fatigues will produce a lower maximal force value than either single condition alone (mental fatigue only or physical fatigue only).

1.9.2 The potential application of knowledge gained from this study.

The results of this study will offer quantitative evidence of how mental and physical fatigue affects the force production of rugby players in the scrum and subsequent scrummaging performance. Data from this study would enhance players and coach’s abilities to manage training and match strategies in order to minimize any detrimental effect that mental and/or physical fatigue may cause. For example, if mental fatigue is found to reduce the maximal force production of rugby players, an opposing coach may instruct their team to use more 'misleading/dummy' players in order to increase the cognitive demands on their opponents. Similarly, if physical fatigue is found to have a detrimental effect on the maximal force production of rugby players, a coach may instruct their team to focus on engaging the opposing team with repeated 'breakdowns' in order to physically exhaust their opponents. Subsequently, results from this study may be used to improve the effectiveness of rugby training to better prepare players for competitive matches.

2.0 Methods

The experimental method chosen for this thesis was of a randomized, crossover, experimental design.

2.1 Ethical Considerations.

In order to carry out this research it was essential that our procedures and protocols met the requirements as set out by Vetenskapsrådet (2002) as well as being approved by the Regional Ethics Review Board of Stockholm. The four general criteria that were met involved the information requirement, consent requirement, confidentiality requirement and the use of information requirement.

All participants were given oral and written information regarding their role in the study and what it entailed, as well as information regarding their data collection, confidentiality, and possible risks of participating in the study. They were also informed that they could withdraw their data and information/participation at any time without reason and consequence.

Participants were asked to read the information form thoroughly before giving written consent in order to take part in the study. Participants were further reminded that all
results are confidential and cannot be shared with any third party e.g. teammates, coach, etc. Each participant was subsequently assigned a subject number in lieu of their real names in order to further protect their identity throughout the study. All information and data collected from the participants was stored within a secure laboratory within the Swedish School of Sport and Health Sciences, Stockholm. No biological material was collected in this study. All information collected was used explicitly for use within this study and was not supplied to a commercial enterprise or used for any non-scientific purposes. The Stockholm Regional Ethics Committee (EPN) obtained ethical approval for the study.

2.1 Subjects

Ten physically active male adults (Mean age = 27.4 ± 3.92, Weight =102.9kg ± 10.96) volunteered to take part in this study. Subjects were recruited via direct contact with local rugby union football clubs and “word of mouth” among rugby players. All volunteers were active rugby union players in local and/or national teams. All participants reported to be physically healthy and injury free before participating in the study. Each subject gave written consent before the study. All participants were given written and verbal information describing the protocols and procedures of the study as well as information regarding the aims of the study i.e. to investigate the effect of physical and mental fatigue on rugby scrummaging ability. However, all participants were naive to the hypotheses of the study. A six-pack of beer (Newcastle Brown Ale, UK), as well as the opportunity to quantitatively measure their scrummaging performance was used as an incentive to take part in the study. All participants were informed not to ingest any products that contain nicotine or caffeine in the hours before testing. At the end of the study, participants were debriefed and thanked for their participation.

2.2 Experimental Protocol

Subjects visited the lab on two separate occasions. During both the first and second visit, the experimental procedures were explained and subjects were invited to perform five practice attempts on the scrummaging machine in order to familiarize themselves with apparatus and procedures. During the first visit, the researcher asked participants whether their foot position on the sprint start blocks felt natural and whether they wanted to alter the start blocks position. The position of the start blocks was recorded once the subject felt satisfied and remained unchanged for the duration of the experiment. During each visit, subjects were randomly allocated to perform either the mental fatigue or physical fatigue protocol first and
followed a counterbalanced order. Immediately following each fatigue protocol, the subject’s maximal voluntary isometric rugby scrummaging strength was tested using an Isomed 2000 force dynamometer (Germany), which was fitted with a bespoke rugby scrummaging adapter within the biomechanics and motor control (BMC) lab at the Swedish School of Sport and Health Sciences (Stockholm, Sweden). Mood and Motivation was measured before control measurements and the mental fatigue protocol, as well as after the mental fatigue protocol and physical fatigue protocol.

Figure 2 Schematic of experimental procedure. FM force measurement, BRUMS Brunel mood scale. SIMS Situational intrinsic motivation scale. RPE rate of perceived exertion. PHYS FATIGUE physical fatigue protocol. MENT FATIGUE mental fatigue protocol.

Figure 3. Isomed dynamometer fitted with a prototype scrum adapter. The final version included reinforced steel armature and greater padding.
Each visit lasted no more than 120 minutes and all visits were completed within 2 weeks of each other. All participants were asked to refrain from physical training 48hrs before the lab visit and were asked to declare whether they had taken any medicine or had any acute illness or injury prior to testing.

2.2.1 Mental Fatigue Protocol

Mental fatigue was induced using a modified incongruent version of the stroop-word task for 30 minutes on a personal computer within the BMC lab. This task involved responding to a randomized list of words (e.g. blue, green, yellow, red) that appeared on the computer screen in various colours. The subject was to respond to the colour of the ink and not to the meaning of the word (e.g. the word “blue” appearing in yellow ink would correspond to the answer “yellow”, etc.). However, for the incongruent component of the task, subjects were to ignore these general rules for words that appeared in red ink and instead respond to the meaning of the word (e.g. the word “green” appearing in red font would correspond to the answer “green”, etc.). Feedback on performance was presented on the screen following every response the subject made. The feedback indicated whether the answer was correct or incorrect, response time and the percentage of correct responses made so far. Subjects responded to the stimuli using keys on the keyboard (A= Red, S=Blue, K=Green, L= Yellow). A key for these responses was present at all times on the bottom of the screen. Furthermore, all subjects were given a short trial with the software in order to familiarize themselves with the protocol before starting the 30-minute task. The task was available in either English or Swedish.
2.2.2. Physical Fatigue Protocol

General physical fatigue was induced by subjects performing squats until failure using a smith machine in the LTIV lab at the Swedish School of Sport and Health Sciences. The barbell was loaded so that the total weight corresponded to 70% of the subject’s body weight. Subjects were instructed to perform as many squats as possible until they were unable to return to the top of the squat position i.e. to failure. A successful squat was acknowledged when the barbell touched the rubber stopper of the smith machine. The total numbers of squats were recorded for each set and five sets were performed with 60 seconds of recovery time between sets. Immediately following the physical fatigue protocol, participants walked back to the BMC lab, which took no more than 5 minutes, and were offered a glass of water prior to testing their isometric rugby scrummaging strength.

2.3 Neuromuscular Tests

Subjects performed maximal isometric strength tests on an Isomed 2000 force dynamometer fitted with a bespoke rugby scrummaging adapter. The adapter consisted of two steel struts that protruded from a steel frame and fitted with multiple layers of foam padding in order to protect participant’s shoulders during the initial impact of scrummaging, as well as for general comfort and to replicate the type of scrummaging equipment frequently used by rugby clubs. A wooden frame was constructed on the floor and sprint blocks were fastened into the structure. A coordinate system was drawn onto the wooden structure so that the sprint blocks could be easily relocated to each participant preferred foot position. The Isomed 2000 dynamometer (Hemau, Germany) was also secured to the ground using steel bolts and specially made wedges in order to eliminate movement during testing. Data was collected using Spike2 software (Cambridge, England). Total force, as well as the force applied by either the left or the right shoulder were analysed by the software at a frequency of 100Hz and measured in Newtons. Participants performed five maximal isometric muscular voluntary contractions (MVCs) against the scrummaging pads, participants were required to perform a maximal isometric MVC for a duration of five seconds and were to follow verbally given binding procedures, in an effort to simulate a live scenario i.e. “Crouch, Bind, Set”. The researcher would give verbal encouragement throughout the scrum attempt and would say “stop” once five seconds of scrummaging had elapsed.
2.4 Psychological Measures

2.4.1 Language
All psychological measures were provided in both English and Swedish. Participants were asked to select the language in which they felt most competent.

2.4.2 Motivation
Motivation towards the scrummaging task was assessed using the Situational Intrinsic Motivation Scale (SIMS). The SIMS is a 16-item self-report inventory that is designed to measure the degree of self-determination towards a task (i.e. intrinsic motivation, identified regulation, external regulation and amotivation). Intrinsic motivation towards a task signifies that an individual engages in a task purely for the pleasure and satisfaction of the task. (Deci 1971). Identified regulation towards a task signifies that a behaviour is valued and perceived as being chosen by oneself but the task is no inherently enjoyable in itself, rather as a means to an end (Guay et al, 2000). External regulation signifies that a behaviour is performed solely for an external reward or to avoid negative consequences (Guay et al. 2000). Extrinsic motivation signifies that a behaviour is undertaken in order to achieve goals independent to that of the activity (Guay et al, 2000). Each item is rated on a 7-point Likert scale (1 = corresponds not at all and 7 = corresponds exactly.) Scores are then calculated for each individual sub scale via the classification index provided. Reliability and construct validity has been established for SIMS and found to be suitable for both field and laboratory settings (Standage et al. 2003).

2.4.3 Mood
The Brunel Mood Scale (BRUMS) developed by Terry, et al (2003). The questionnaire contains 24 items (e.g. annoyed, confused, depressed, exhausted, anxious, and active) divided into six respective sub scales: anger, confusion, depression, fatigue, tension and vigour. A 5-point Likert scale (0 = not at all; 1 = a little; 2 = moderately; 3 = quite a bit: and 4 = extremely) was used to respond to each item. Resulting in a raw score of 0-16 for each sub scale (four items per scale). For the purpose of this study, we report the fatigue and vigilour sub scales. An increase in subjective fatigue/vigour is a well known marker of fatigue in athletes (Budgett, 1998).
2.4.4 Perceived Exertion

Participants were asked to rate their perceived exertion using the Borg 6-20 scale (Borg 1970) immediately following each scrummaging attempt against the force dynamometer. Perceived exertion was defined as a subjective rating of exertion, based upon physical sensations a person experiences during exercise. A large diagram of the Borg 6-20 scale was positioned to the left of the force dynamometer so that participants could view the scale immediately following their scrummaging attempt. A rating of 6 on the scale corresponds to the sensations of being at rest and a rating of 20 corresponded to sensations associated with the hardest effort they have experienced during physical exercise. Participants were encouraged to assess their perceived exertion as quickly as possible in an effort for participants not to ‘think too much’.

2.5. Statistical Analysis.

Normal distribution, outliers and sphericity were tested before continuing with our statistical analysis in order to fore fill the assumptions required for statistical tests. Greenhouse-Geisser corrections were made is sphericity was violated. A one-way repeated ANOVA was used to compare the mean force production measurements under each condition (Control day 1, Control day 2, Mental fatigue, physical fatigue, Mental and physical fatigue, Physical and mental fatigue). The peak force values were calculated by locating the highest peak force during the sustained push and calculating the mean value within a 1 second range of this peak at a frequency of 100Hz. A Tukey correction was also used during post-hoc analysis in order control for Type I errors during multiple comparisons. Statistical analyses were conducted using the Statistical Package for the Social Sciences, version 19 for Mac OS X (SPSS Inc., Chicago, IL, USA). A significance level of \( p < 0.05 \) was used for all analyses. All data is presented as (Mean ± Standard Deviation).

3. Results

3.1 Physical Performance

A repeated measures ANOVA using one factor found a significant difference between conditions (Controls, Single, Combined) \( F = (4.36) = 7.0734 \ P = 0.000261 \) (See Table.1)
Repeated Measures Analysis of Variance (Rugby Scrum Data in Rugby Scrum Stat 3)
Sigma-restricted parameterization
Effective hypothesis decomposition: Std. Error of Estimate: 713,7040

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Table 1. Results of repeated measures ANOVA

![Figure 5](image-url)  
Figure 5. Mean peak force differences between conditions.
An initial post hoc analysis using Tukey range test found no significant differences between the mean peak force values of Control day 1 and Control day 2 ($P=0.992$). Subsequently, it was decided to calculate the mean of both control days in order to produce a single control value. This value was then used in a subsequent analysis.

A post hoc analysis using a Tukey range test found significant differences ($p=<0.05$) between mean peak force values of; the physical fatigue condition vs. control (PF = 1740 ± 342N vs. CON = 2007.5 ± 359N. $P=0.00089$), the physical & mental fatigue (PMF) condition vs. control (PMF = 1750 ± 348N vs. CON = 2007.5 ± 359N. $P=0.0014$) and the mental & physical fatigue (MPF) condition vs. control (MPF = 1818 ± 335N vs. CON = 2007.5 ± 359N. $P=0.026$) (See Table 2). No significant differences were found between the mean peak force values of; the mental fatigue only (MF) condition vs. control (MF = 1912 ± 321N vs. CON = 2007.5 ± 359N. $P=0.52$), PMF vs. MF (PMF = 1750 ± 348N vs. MF = 1912 ± 321N, $P=0.078$), MPF vs. MF (MPF = 1818 ± 335N vs. MF = 1912 ± 321N, $P=0.7$) and PF vs. MF (PF = 1740 ± 342N vs. MF = 1912 ± 321N. $P=0.053$.) Although this low P value does show a clear tendency to significance.

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Figure 6. Mean peak forces in all conditions.

Figure 7. Peak mean force values of all variables according to day.
3.2 Manipulation Checks

A Friedman test found statistically significant differences in the reported subscales of vigour within the BRUMS Questionnaire, between the various conditions $X^2(2) = 17.89$, df=7, $p=0.012$. Post hoc analysis with Wilcoxon signed-rank tests found significant differences for the vigour subscale of the BRUMS questionnaire on day 1 include; ‘before control’ (9.6 ± 3.06) vs. ‘before mental fatigue protocol’ (7 ± 3.13) ($Z=-2.203$, $p=0.028$), ‘before control’ (9.6 ± 3.06) vs. ‘after mental fatigue protocol’ (5.1 ± 2.6) ($Z=-2.705$, $p=0.007$), 'before mental fatigue protocol’ (7 ± 3.13) vs. ‘after mental fatigue protocol’ (5.1 ± 2.6) ($Z=-2.063$, $p=0.039$).

No significant differences were found in the following conditions on day 1:
‘Before control’ (9.6 ± 3.06) vs. ‘after physical fatigue protocol’ (7.3 ± 3.09) ($Z=-1.548$, $p=0.122$), 'before mental fatigue' (5.1 ± 2.6) vs. ‘after physical fatigue protocol’ (7.3 ± 3.09) ($Z=-1.737$, $p=0.810$),
‘after mental fatigue protocol’ (5.1 ± 2.6) vs. ‘after physical fatigue protocol’ (7.3 ± 3.09) ($Z=-1.178$, $p=0.239$).

Significant differences for the vigour subscale of the BRUMS questionnaire on day 2 include:
‘before control’ (7.33 ± 2.83) vs. ‘after mental fatigue’ (4.9 ± 3.21) ($Z=-2.209$, $p=0.027$),
‘before control’ (7.33 ± 2.83) vs. ‘after physical fatigue’ (5.2 ± 2.25) ($Z=-2.536$, $p=0.040$),
‘before mental fatigue’ (8.3 ± 2.58) vs. ‘after mental fatigue’ (4.9 ± 3.21) ($Z=-2.536$, $p=0.011$),
‘before mental fatigue’ (8.3 ± 2.58) vs. ‘after physical fatigue’ (4.9 ± 3.21) ($Z=-2.694$, $p=0.007$).

No significant differences were found in the following conditions on day 2:
‘before control’ (7.33 ± 2.83) vs. ‘before mental fatigue’ (8.3 ± 2.58) ($Z=-0.922$, $p=0.357$),
‘after mental fatigue’ (4.9 ± 3.21) vs. ‘after physical fatigue’ (4.9 ± 3.21) ($Z=-0.358$, $p=0.721$).

A Friedman test found statistically significant differences in the reported subscales of fatigue within the BRUMS Questionnaire, between the various conditions $X^2(2) = 34.856$, df=7, $p=0.000$. Post hoc analysis with Wilcoxon signed-rank tests found significant differences for
the fatigue subscale of the BRUMS questionnaire on day 1 include; ‘before control’ (3.3 ± 2.11) vs. 'after physical fatigue protocol’ (9 ± 3.528) (Z=-2.615, p=0.009), ‘before control’ (3.3 ± 2.11) vs. ‘before mental fatigue protocol’ (6.6 ± 2.22) (Z=-2.408, p=0.016), ‘before control’ (3.3 ± 2.11) vs. 'after mental fatigue protocol’ (7.7 ± 3.23) (Z=-2.810, p=0.005), ‘after physical fatigue protocol’ (9 ± 3.528) vs. 'before mental fatigue protocol’ (6.6 ± 2.22) (Z=-2.254, p=0.024),

No significant differences were found in the following conditions on day 1:
‘after physical fatigue protocol’ (9 ± 3.528) (9 ± 3.528) vs. ‘after mental fatigue protocol’ (7.7 ± 3.23) (Z=-1.178, p=0.239), ‘before mental fatigue protocol’ (6.6 ± 2.22) vs. ‘after mental fatigue protocol’ (7.7 ± 3.23) (Z=-1.027, p=0.304).

Significant differences found for the fatigue subscale of the BRUMS questionnaire on day 2 include; ‘before control’ (3.89 ± 3.1) vs. 'after mental fatigue protocol’ (6 ± 3.13) (Z=-2.388, p=0.017), ‘before control’ (3.89 ± 3.1) vs. 'after physical fatigue protocol’ (8.3 ± 3.82) (Z=-2.552, p=0.011), ‘before mental fatigue protocol’ (3.6 ± 3.03) vs. 'after mental fatigue protocol’ (6 ± 3.13) (Z=-2.514, p=0.012), 'after physical fatigue protocol’ (8.3 ± 3.82) vs. 'before mental fatigue protocol’ (3.6 ± 3.03) (Z=-2.673, p=0.008), 'after physical fatigue protocol’ (8.3 ± 3.82) vs. 'after mental fatigue protocol’ (6 ± 3.13) (Z=-1.960, p=0.05).

No significant differences were found 'before mental fatigue protocol’ (3.6 ± 3.03) and 'before control’ (3.89 ± 3.1) (Z=-1, p=0.317).

3.3 Motivation
Following a Friedman test, no significant differences were found between any of the subscales of motivation i.e. intrinsic, identified regulation, extrinsic regulation and amotivation, across the fatigue and control conditions. Intrinsic motivation; $X^2(2) = 4.67$, df=7, $p=0.700$, Identified regulation; $X^2(2) = 2.067$, df=7, $p=0.956$, Extrinsic regulation; $X^2(2) = 6.984$, df=7, $p=0.430$ and amotivation; $X^2(2) = 3.907$, df=7, $p=0.790$. Values for intrinsic motivation towards the scrummaging task after the mental fatigue protocol: Day 1 = 19.9 ± 5.01, Day 2 = 20.1 ± 4.93 compared to their controls: Day 1 = 19.8 ± 6.97, Day 2 = 21.2 ± 3.96. Identified regulation towards the scrummaging task after the mental fatigue protocol: Day 1 = 20.5 ± 5.17, Day 2 = 20.9 ± 4.46 compared to their controls: Day 1 = 19.6 ± 6.33, Day 2 = 21.2 ± 3.52. Scores for extrinsic motivation towards the scrummaging task after the
mental fatigue protocol: Day 1 = 7.5 ± 6.54, Day 2 = 7.1 ± 6.08 compared to their controls: Day 1 = 7.6 ± 6.52, Day 2 = 7.1 ± 5.12. Scores for amotivation towards the scrummaging task after the mental fatigue protocol: Day 1 = 6.8 ± 4.13, Day 2 = 6.6 ± 3.69 compared to their controls: Day 1 = 6.4 ± 4.38, Day 2 = 7.1 ± 3.45.

Figure 8. Changes in motivation reported before and after the various conditions.

### 3.4. Perceived Exertion

A Friedman’s test performed on the RPE values gathered during scrummaging under the various conditions did find significant differences $X^2(2) = 19.75$, df= 5, p=0.001. Post hoc analysis using the Wilcoxon signed-rank test found significant differences between the mean RPE values of subjects in the following conditions:

- Mental fatigue (15.52 ± 1.23) vs. Physical fatigue (16.72 ± 1.35) ($Z$=−2.091, $p$=0.037),
- PMF (16.24 ± 1.13) vs. MPF (17.78 ± 1.13) ($Z$=−2.191, $p$=0.028),
- MPF (17.78 ± 1.13) vs. Mental fatigue (15.52 ± 1.23) ($Z$=−2.805, $p$=0.005),
- MPF (17.78 ± 1.13) vs. Control day 2 (15.52 ± 1.48) ($Z$=−2.666, $p$=0.008),
MPF (17.78 ± 1.13) vs. Control day 1 (15.68 ± 1.8) (Z=-2.547, p=0.011) and
MPF (17.78 ± 1.13) vs. Physical fatigue (16.72 ± 1.35) (Z=-2.243, p=0.025).

No significant differences were found between:
Control day 1 (15.68 ± 1.18) vs. Control day 2 (15.52 ± 1.48) (Z=-0.819, p=0.413),
Control day 1 (15.68 ± 1.18) vs. Physical fatigue (16.72 ± 1.35) (Z=-1.543, p=0.123),
Control day 1 (15.68 ± 1.18) vs. PMF (16.24 ± 1.13) (Z=-1.684, p=0.092),
Control day 1 (15.68 ± 1.18) vs. Mental fatigue (15.52 ± 1.23) (Z=-0.051, p=0.959) and
Control day 2 (15.52 ± 1.48) vs. Mental fatigue (15.52 ± 1.23) (Z=-0.205 p=0.838).

Figure 9. Changes in the mean ratings of perceived exertion reported during scrummaging under the various conditions.
4. Discussion

4.1. Discussion of methods

The crossover design used for this experiment was decided as an appropriate method for investigating the effects of single fatigue conditions (mental or physical fatigue) as well as the different combination (mental and physical fatigue or physical and mental fatigue) on the force production abilities of rugby players in this study. This experimental design allows us to retain a good validity compared to other experimental designs. For example, if we had performed all the tests within a single session, it is likely that the effects of each fatigue protocol would interfere with each other and, subsequently, would not allow us to confidently attribute observations to a single condition. For example, if a subject performs the physical fatigue protocol first, followed by measurement of their force production during a scrummage, we could confidently attribute their force production values to a physically fatigued condition only. However, if they then perform a mental fatigue protocol immediately after, then it becomes difficult to attribute their subsequent force production values to mental fatigue only as the effects of the previous fatigue protocol would likely still be present and vice versa.

In fact, it is this assumption that each protocol will interfere with each other when performed in quick succession that is the premise for our combined conditions. In order to add more confidence to this assumption, psychological questionnaires are used in order to monitor states of mental fatigue and motivation during the study. Furthermore, the duration of effects elicited by physical fatigue have already been established in previous studies (Byrne & Eston, 2002) and allow us to confidentially arrange our design in a manner that has little interference between conditions as possible.

Previous of studies (Marcora et al, 2009; Pageaux et al, 2013) had used a single-blind design, which would have been desirable; in order reduce the risk of bias or placebo effects. However, it was decided that the use of a single-blind design would have increased each individual’s lab visit by approximately 30-60 minutes i.e. totalling the duration of each lab visit to 2.5-3 hours. This duration was deemed to be inappropriate as it would hinder recruitment from an already small population i.e. rugby players in Stockholm that play a forward position. Similarly, use of a double-blind experimental procedure was not possible due to a lack personal to assist with the research process. For example, it would take several
independent researchers to effectively collect data within a double-blind set-up as an independent research would be required to instruct subjects through each protocol, in order preserve the naivety of the researcher collecting scrummaging force data. Moreover, there may be some methodological difficulties of using 'decoy' protocol within both single and double blind experimental design. Marcora et al (2009) used a 30-minute mentally fatiguing task and a 30 minute emotionally neutral documentary as a 'decoy' task in order to maintain a single-blind procedure. However, this becomes more difficult when trying to select a 'decoy' task for physical fatiguing, as any task requiring physical activity will induce fatigue to vary degrees.

The primary risk of injury that participants were exposed to during this study was light bruising of the shoulders, caused by engagement with the scrummaging machine and soft-tissue injuries caused by improper engagement technique. Steps were taken to minimize the risk of bruising to individuals by heavily padding the scrummaging machine in order to cushion the impact of engagement. To minimize the risk of soft-tissue injuries cause by improper engagement technique, we required that all participants have recent experience within a scrum (i.e. been involved in a scrum within the last 12 months) and that all participants actively played within a forward rugby position at the time of taking part in the study. This risk of injury is also not dissimilar to the types of injuries that forward rugby players routinely encounter during normal rugby training and matches. Moreover, I propose that scrummaging within a well-controlled laboratory environment may well be a safer alternative to on-field scrummaging due to fewer uncontrollable forces acting upon the player.

The mentally fatiguing task used for this experiment can be considered an appropriate and relevant method of inducing mental fatigue in rugby players. This is because the task requires sustained attention, error monitoring, response inhibition and effort-based decision making, which are psychological demands that a rugby player will likely experience during the course of a rugby match (see section 1.3). Although other studies Martin et al (2014) and Marcora et al (2009) had used a longer 90 minute AX-continuous performance task in order to induce fatigue. It was decided that a 90-minute task would negatively affect participant recruitment for the study. Furthermore, previous studies had found that the incongruent stroop task successfully induced mental fatigue in athletes. (Rozand et al, 2014)

This physical fatigue protocol was modelled on a similar protocol that had been applied by Byrne & Eston (2002). In their study, they instructed participants to perform 10
sets of 10 repetitions with a barbell loaded with 70% body weight and subsequently showed reduced isometric, concentric and eccentric strength abilities of the knee flexors. In our protocol, the barbell squat was replaced with a smith machine squat with rubber stoppers on the smith machine positioned so that travel of the bar was stopped when the participant’s knee was flexed 90° relative to the ground.

I decided to replace the barbell squat as used in Byrne & Eston’s (2002) study with a smith machine squat as I believed this approach would be feel safer for the participants, particularly towards the point of failure due to the greater stability provided by the smith machines construction. Furthermore, during pilot testing, I found that performing 5 sets of squats until failure required less time and elicited similar impairments in power production (measured using jump squats) as was reported in Byrne & Eston’s (2002) study.

4.2 Discussion of Results

The aims of the present were to investigate the effects of physical fatigue, mental fatigue and their combinations on rugby player’s abilities to produce force during a scrum. Our results showed that mental fatigue did affect the peak force produced by rugby players during scrummaging; this result allows us to fail to reject our null hypothesis. Furthermore, in agreement with our alternative hypothesis, physical fatigue does negatively affect a rugby player’s ability to produce force during a scrum. However, we must fail to accept our second alternative hypothesis, as the combinations of physical and mental fatigue did not exacerbate the negative effects of physical fatigue alone on force production during scrummaging.

4.2.1 Physical Fatigue and Performance

In accordance with previous studies, physical fatigue induced a 13.33% reduction in the mean peak force produced during the sustained push of a rugby scrum. Despite no significant changes in measures of motivation, it is likely that this reduction in mean peak force is attributable to alterations of both peripheral processes and muscle damage. Although Gandevia (2001) suggested that physical fatigue is a combination of both peripheral and central processes. It is unlikely that the short-duration of high intensity activity during the control force testing and physical fatigue protocol was sufficient to cause significant disturbance of central processes (Lepers et al, 2000; Millet & Lepers; 2004; Skof & Strojnik, 2006).
4.2.2. Mental Fatigue and Performance

Manipulation checks found that significant reduction in the vigour subscale of the BRUMS questionnaire before and after mental fatigue protocols on both days. However, values for the fatigue subscale of the BRUMS questionnaire was only found to have significantly increased in day 2 only. An explanation for the lack of significant difference in fatigue values during Day 1 may be due to the differing order of the protocols i.e. when the physical fatigue protocol was performed before the mental fatigue protocol the increased feeling of fatigue may have remained elevated for the duration of the session with the mental fatigue protocol having no exacerbating effect.

Scrummages performed under a mentally fatigued state resulted in a reduction of 4.75% reduction in mean peak force. However, this difference was not found to be significantly different to the control measurements \((P<0.05)\) and may be the result of fatigue induced during the control measurements and familiarization with the scrummaging machine. Nonetheless, the lack of significant effect of mental fatigue on a component of anaerobic performance is consistent with the results of (Pageaux et al, 2013; Rozand et al, 2014; Martin et al, 2015).

Furthermore, as the mean peak force production of rugby players did not significantly from the control measurements, it is tenable to speculate support for Pageaux et al. (2013) and Rozand et al (2014), i.e. that mental fatigue does not exacerbate central fatigue. In fact, Van Duinen et al (2007) found that central fatigue during abduction of the index finger is associated with altered activity in different regions of the brain (supplementary motor area, parts of the paracentral gyrus, right putamen and part of the left parietal operculum). Subsequently, mental exertion caused by response inhibition, error monitoring and sustained attention has not been found to affect these areas of the brain. (Mostofsky and Simmonds, 2008).

4.2.3. Combinations of Mental and Physical fatigue on Performance.

Whilst both MPF and PMF conditions elicited significantly lower mean peak force measurements when compared to the control, these reductions in mean peak force were not larger than forces observed when participants were physically fatigued only, i.e. the combination of fatigued conditions did not exacerbate the effects of physical fatigue only. As
mental fatigue was not found to have a significant effect on force production, it may be assumed that the reduction found in the combination of fatigues is wholly attributable to physical fatigue. Whilst the MPF did elicit a slightly greater decrease in mean peak force values, compared to the PMF condition, this difference was not significant ($P=0.8$). This too, would agree that mental fatigue does not effect on mechanisms of central fatigue (Rozand et al, 2014).

### 4.2.4 Perceived exertion and Performance.

Our results showed that RPE only significantly increased, when compared to RPE measurements at control during the MPF condition. Whilst several studies have shown that RPE values tend to increase when mentally fatigued in endurance tasks e.g. cycling (Brownsberger et al, 2013; Marcora et al, 2009; Pageaux et al, 2014.) It is believed that mental fatigue, induced via means of sustained attention, error detection and decision making (Carter et al, 1998; Walton, et al, 2006) may influence activity of the ACC and has been associated with an increased perception of exertion during exercise (Williamson et al, 2001; 2002; 2006). However, it may be difficult to extrapolate the findings of Williamson et al (2001; 2002; 2006) to the present study as their research investigated the changes in neurological activity during aerobic forms of exercise, not anaerobic exercise and elicited activity of the ACC via hypnosis, not an incongruent stroop task.

Our data agrees with findings by Martin et al (2014) that found that RPE did not increase in mentally fatigued participants during anaerobic performances and may be explained by the limited demands placed on the cardiovascular system during short bouts of maximal isometric muscle contractions. Subsequently, engagement towards the task may not be effected by mental fatigue. That is, that mental fatigue does not negatively on motivation towards the task. Moreover, increases in RPE found during the MPF condition were also found to have no effect on subscales of motivation. These results provide preliminary evidence that ratings of perceived exertion do not interact with constructs of motivation.

### 4.2.5 Motivation, mental fatigue and force production.

Despite significant increases in mental fatigue, no significant differences in the subscales of SIMS (Intrinsic, identified regulation, extrinsic regulation and amotivation) were found during this study. These results disagree with the rationale for our hypothesis that increased
RPE, induced via mental fatigue, will correlate to a decrease in motivation and a subsequent withdrawal from the task and lower mean peak force values.

### 4.3 Applications of this research

This research further supports the current body of research regarding the effects of mental fatigue on force production. Within rugby union, it is advisable that teams focus on training that increases players’ rate of recovery, as well as the use of pacing strategies and nutrition in order to minimize the effects of physical fatigue on player’s ability to exert a maximal force during scrummaging. Furthermore, although mental fatigue does not affect the force production abilities of rugby players during the scrum, the development of mental fatigue during a rugby match and its effects on other components of rugby performance warrants further investigation.

### 4.4 Limitations of this Study

The external validity may be questionable in this study as individual rugby scrummaging is not performed during rugby matches and the biomechanical demands of scrummaging within an entire forward pack are likely different. For example, during our testing there are no forces being applied by other teammates during scrummaging, furthermore there is no “give” in the scrummaging machine, which would otherwise be expected during a live-scrum. Participants did report that scrummaging against a static machine did “feel different” compared to their experience of scrummaging during live matches. A potential solution to one of these problems is to measure changes in isokinetic strength, rather than isometric strength, as this would allow the scrummaging adapter to move upon impact and perhaps give the rugby player a more realistic simulation of a scrum.

Participants also expressed soreness and a reluctance to forcefully influence the scrummaging machine after multiple attempts. In order to minimize these complaints, participants were reminded that their engagement force was irrelevant to the study and that only the peak force during their sustained push would be analysed, therefore a softer engagement with the scrummaging may be adopted. Again, this may reduce the external validity of our study as participants may then have modified their scrummaging technique in order to reduce discomfort. This threat could be reduced in further studies with better padding of the scrummaging machine and/or more “give” in the scrummaging apparatus (i.e. the scrummaging machine moves backwards upon impact.)
The small sample size of 10 participants does not allow give our data significant power. A sample size result of 15 subjects with an actual statistical power of 82% was computed using priori power analysis with G*Power software (version 3.1.6, Universität Düsseldorf, Germany) and set at $\alpha = 5\%$, $\beta = 80\%$ and effect size (ES) of 0.8 (classified as large ES by Cohen’s ES score). Furthermore, Rugby is firmly a recreational sport in Sweden and players may subsequently compete at a lower level than their foreign counterparts, where rugby is more widely and professionally played. Coupled with our low sample size it may be difficult to extrapolate these findings to the sport, in general. It may be possible to increase the sample size by approaching rugby football clubs in areas outside of the Stockholm area and offering a financial incentive to take part in the study.

There is no differentiation between muscle fatigue or muscle damage in this study, subjects did complain of muscle soreness for several days after the study. Without the collection of biomarkers related to muscle fatigue, it is difficult to accurately determine whether the underlying mechanisms that caused the reduction in mean peak force production were due to metabolic changes occurring at the muscle or damage caused to the myofibrils themselves. Indeed, it is likely that subjects in our study experienced elements of both muscle fatigue and damage during their physical fatigue protocol. In defence of this limitation, it is plausible that both muscle fatigue and muscle damage would occur during live rugby training/matches as well.

During collection of RPE data during this study, it was also observed that some participants might have misinterpreted the usage of the RPE scale following scrummaging attempts. It is possible that some participants used the scale as a subjective measurement of their performance rather than as a rating of their perceived exertion during the task. Furthermore, in order to streamline the process of data collection, we permitted pairs of participants to be tested simultaneously. Whilst this method did not affect the timing of protocols and order of testing, it could be argued that the presence of a teammate during testing may have affected scrummaging performance. However, within live rugby training, players seldom practice scrummaging independently. Therefore, the presence of teammates during scrummaging would not be an inaccurate simulation of live rugby scrum practice.
5. Conclusion

Results from this study allow us to accept hypothesis that physical fatigue reduces the ability of rugby players to produce maximal voluntary contractions during a scrum. However, we fail to accept hypothesis that mental fatigue reduces the ability of rugby players to produce maximal force and that the combination of mental and physical fatigue does not exacerbate the effects of physical fatigue alone.

References


Bilaga 1

Literature Search

**Aim and hypotheses:** The aim of this study is to investigate the effects of physical fatigue, mental fatigue and their combinations on the ability of rugby players to produce force during rugby scrummaging. We expect to accept the null hypothesis that there will be no difference between the mean force produced by mentally fatigued individuals and the mean force produced during their control. Furthermore, an alternative hypothesis is that the mean force produced by physically fatigued individuals will be significantly lower than either the mean force produced during their control or the mean force produced when mentally fatigued. Our final hypothesis is that the combination of either Mental fatigue and physical fatigue or physical fatigue and mental fatigue (their combination is dependent on the order that the protocols are administered) will be significantly lower than than the mean force produced by either their control or mental fatigue or physical fatigue conditions alone.

**Which searchwords were used:**

- Mental fatigue
- Physical fatigue
- Anaerobic
- Aerobic
- Peripheral mechanisms of Fatigue
- Mechanisms of mental fatigue
- Stroop Task
- Incongruent Stroop Task
- High intensity Mental Fatigue

**Where have you searched?**

- GIHs online database
- PubMed
- Google Scholar
### Searches that gave relevant results

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### Comments

None.
Appendix. 1

Participant consent and information form

Till Dig som kommer att delta som försöksperson i en undersökning

Varför gör vi denna undersökning?

Det har länge varit känt att fysisk trötthet kan påverka människors kraft produktions förmågor men det är bara nyligen som effekten av mental trötthet på dessa förmågor har undersömts. Dock har ingen forskning undersökt effekten av både fysisk och mental trötthet samtidigt. Vi tror att kombinationen av dem två troligt kommer att inträffa under matchen och resultatet från denna studie kan hjälpa strukturera en ny strategi inom rugby för att minimera den möjliga effekten av antingen mental eller fysisk trötthet. För att kunna bedöma hur mental och fysisk trötthet kan påverka kraftförmågan i ’rugby scrummaging’, behöver vi jämföra din kraftproduktion under olika kombinationer. Detta sker i Biomekanik och Motoriska Kontroll labbet (BMC) på Gymnastisk och idrottshögskolan (GIH).

Tillfrågan om deltagande

Vi frågar dig om du samtycker till att delta i denna undersökning.

Studiens genomförande

Deltagande i studien omfattar undersökningar med magnetkamera, ultraljud, dynamometri (mätning av muskelstyrka vid fotleden) samt mätningar med den så kallade Neuroflexor apparaten (En stegmotor rör en fotplatta där patientens fot fästs så att foten rörs i förbestämda hastigheter. En passiv rörelse i fotleden produceras av stegmotorn med konstant hastighet varpå motståndet registreras.) vid Laboratoriet för Biomekanik och Motorisk Kontroll (BMC), GIH. Magnetkameran tar en bildserie av dina lårben medan du är vaken. Undersökning med magnetkameran tar mindre än en timme och vid Karolinska Universitetssjukhus, Huddinge.

Vid BMC ska dina kraftproduktions förmågor mätas i en dynamometer med en specialbyggd scrummaging adapter, som mäter din kraftproduktion i en rugby scrummaging position. Efter flera försök ska du antigen gå i genom en fysisk trötthet protokoll (knäböj med 30% kroppsvikt till slut) eller mental trötthet protokoll (30 minuters modified incongruent stropp task på datorn). Direkt efter protokollen mäter vi din kraftproduktions förmåga igen. Både innan och efter varje kraftproduktions mätning ska vi fråga dig att uppskatta hur du känner dig (Mental trötthet, fysisk trötthet och hur hårt du tycker att du pressat sig själv under kraft mätningen).

Hela undersökningen sker över två olika dagar. Varje besök borde ta cirka 1 timme och sker under 5-7 dagars mellanrum.

Risker

Risk för fysiska skador är små och mindre sannolika än i vanlig rugby scrummaging på fältet men på grund av den explosiva natur rörelsen kräver kan man ändå få skador. Den statiska natur av scrummaging mot dynamometern och avsaknaden av kraft applicerad från andra människor reducerar risken för skador ännu mer. Dessutom finns det liten risk av fysiska
skador under fysisk trötthet protokollen e.g. muskel vrickning, sträckning, diskbråck.
Det finns inga risker med det mentala trötthets protokollet. Effekten av mental trötthet avklingar efter några minuter/timmar.

**Vad händer om jag inte vill vara med?**
Ditt deltagande är helt frivilligt och ni kan när som helst avbryta deltagandet utan att ange något skäl och utan att det på något sätt påverkar vården i övrigt.

**Hantering av data**

**Personuppgiftsansvar**

**Sekretess**
Din identitet skyddas genom att ditt namn ersätts av ett nummer, som endast den ansvariga för studien har tillgång till. All data är sekretesskyddad.

**Försäkring**
Försökspersoner försäkring gäller.

**Ansvarig för studien**
MSc Student - Cai Owain Birch
Professor i idrotts inriktningar rörelse - Toni Arndt

**Ytterligare information**
Om du har frågor är du välkommen att kontakta undertecknade.
Om du vill delta i undersökningen, vänligen lämna svarsblanketten i det frankerade kuvertet.
Stockholm 2016-02-08

Cai Owain Birch, MSc Student, cai.birch@student.gih.se
Toni Arndt, Professor i Idrotts inriktningar rörelse, toni.arndt@gih.se
GIH, Lidingövägen 1, 114 33 Stockholm, tel. 08-120 537 00
Appendix 2.
The Situational Motivation Scale (SIMS)

Directions: Read each item carefully. Using the scale below, please circle the number that best describes the reason why you are currently engaged in this activity. Answer each item according to the following scale: 1: corresponds not all; 2: corresponds a very little; 3: corresponds a little; 4: corresponds moderately; 5: corresponds enough; 6: corresponds a lot; 7: corresponds exactly.

<table>
<thead>
<tr>
<th>Why are you currently engaged in this activity?</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Because I think that this activity is interesting.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2. Because I am doing it for my own good</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>3. Because I am supposed to do it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
<td>7</td>
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<tr>
<td>4. There may be good reasons to do this activity, but personally I don’t see any</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>5. Because I think that this activity is pleasant</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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<tr>
<td>6. Because I think that this activity is good for me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>7</td>
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<tr>
<td>7. Because it is something that I have to do</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>8. I do this activity but I am not sure if it is worth it</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>9. Because this activity is fun</td>
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<td>3</td>
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<tr>
<td>10. By personal decision.</td>
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<td>2</td>
<td>3</td>
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<tr>
<td>11. Because I don’t have any choice.</td>
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<td>2</td>
<td>3</td>
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<tr>
<td>12. I don’t know; I don’t see what this activity brings me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>13. Because I feel good when doing this activity.</td>
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<tr>
<td>14. Because I believe that this activity is important to me.</td>
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<td>15. Because I feel that I have to do it.</td>
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<td>16. I do this activity, but I am not sure it is a good thing to pursue it.</td>
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Appendix 3:
The Profile of Mood States-A (BRUMS) (Swedish Version)


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