ASSOCIATION OF THE ACUTE:CHRONIC WORKLOAD RATIO AND INCIDENCE OF INJURY IN PREMIER LEAGUE, MALE HOCKEY PLAYERS

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I, Gabriela Nicolaci Veiga declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of MSc Medicine at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

GVeiga

(Signature of candidate)

19th day of December 2019

To my inspiring parents who pushed me to my limits and showed me just how far I can truly go. Thank you for the unconditional and sometimes overwhelming love and support.

To my siblings who tolerated my mood swings and stress throughout my studies. Thank you for being my best friends even when I was a hassle.

To my soulmate who told me I could even when I felt it was the last thing I was capable of. Thank you for believing in me when I did not.

I would not have gotten through this dissertation without all of you.

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ABSTRACT

The relationship between acute:chronic workload ratios and incidence of injury as well as the relationship between subjective wellness and training load is unclear in premier league male hockey players. This study investigated these relationships to determine if the acute:chronic workload ratio is a useful injury prevention marker and workload management tool for field hockey players. This study also investigated the association between subjective wellness scores (fatigue, sleep quality, general muscle soreness, mood and stress level) and the acute:chronic workload ratio and the session rating of perceived exertion. Fourteen, male field hockey players from the men's first team at the University of the Witwatersrand, Johannesburg participated in the study and during ten weeks of premier league, competition phase. A Google form was completed within thirty minutes of every training session or match. The Google form consisted of questions that allowed for the calculation of the ACWR. No incidence of injury was reported during the ten-week period and the ACWR scores ranged between 0.67 and 1.87. In addition, it was found that the ACWR was associated with general muscle soreness ($p = 0.010$) and sRPE was associated to fatigue ($p = 0.004$), sleep quality ($p = 0.035$) and general muscle soreness ($p < 0.001$). The study did not find an association between the ACWR and injury incidence in this sample of hockey players, yet associations were found between some wellness scores and ACWR and SRPE. Therefore, there may be some merit in the use of subjective wellness measures as workload management tools in field hockey, but further studies are required to find an optimal ACWR for this sport.

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DEFINITION OF TERMS

Workload – the combination of sport and non-sport stressors

External load - the physical work (number of sprints, weight lifted, total distance, etc.) performed by the athlete during competition, training and daily life

Internal load - the individual physiological and psychological response to the external load. It is influenced by genetic factors combined with daily life stressors, environmental and biological factors

LIST OF ABBREVIATIONS

ACWR – acute:chronic workload ratio

RPE – rating of perceived exertion

sRPE – session rating of perceived exertion

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CHAPTER 1 – INTRODUCTION

1.1 General introduction

The primary objective of sports practitioners is to minimise injuries within a team while simultaneously maximising the players' training load. The uniqueness of team sport conditioning lies in the fact that teams will partake in matches against one another over the course of an entire season and then still be required to compete in a finals period at the end of the season. This requires team sports players to maintain a high level of fitness that was developed during the preseason training period, throughout the competition phase while simultaneously recovering and managing fatigue (Coutts & Reaburn, 2008). This fragile balance of training and recovery poses a challenge for sports practitioners, therefore athlete monitoring systems are required to be in place. While monitoring workload through the use of objective measures has been used since the beginning of athlete monitoring, subjective measures (such as session rating of perceived exertion and wellness scores), have only just begun to gain momentum in the world of sports science as an abundance of literature has proven its reliability and validity (Saw, Main & Gastin, 2016). The advantage of utilising subjective measures is that they equate to the athlete's internal load which is specific to each individual athlete. This link between subjective measures and internal load is of importance in training because adaptations to training workload are elicited by the internal load (Impellizzeri, Rampinini & Marcora, 2005).

The acute:chronic workload ratio (ACWR) has been studied extensively over multiple sports disciplines. Studies investigating the viability of ACWR as a workload management tool have been conducted on Australian football players (Colby et al., 2017), rugby players (Hulin et al., 2016), soccer players (Malone et al., 2017) even Gaelic football players (Malone et al., 2016), but there is a lack of studies on hockey players. Hockey is unique from these sports as it uses rolling substitutions during gameplay, which could affect the viability of ACWR as a workload management tool. Furthermore, there is a lack of studies which have investigated the relationship between evidence-based wellness scores and the ACWR. Therefore, this study will investigate ACWR and wellness scores in male hockey players during an in-season phase of premiere league hockey competition. A p value less than 0.05 was considered significant.

1.2 Aim

While an abundance of research has been conducted to understand the association between ACWR and injury in various sports, such research has never been conducted on field hockey players. Furthermore, the association between wellness scores and ACWR has been observed in few sports (college football and professional volleyball) (Sampson et al., 2019; Clemente et al., 2020) and field hockey is not one of them. For that reason, our study sought out to determine if ACWR was related to injury in field hockey and if ACWR was an adequate indicator of injury. In addition to this, we studied the association between wellness scores and ACWR, and sRPE. These results can be used to guide sports practitioners who deal with field hockey players to prescribe and monitor training more accurately in relation to the sport.

1.3 Objectives

- To describe the ACWRs during a premier league, men's hockey season.
- To determine if the ACWR is a predictor of injury in male, premier league hockey players.
- To determine if there is an association between ACWR and wellness scores and the strength of the association.
- To determine if there is an association between sRPE and self-reported wellness in premier league men's hockey team and the strength of the association.

1.4 Literature survey

Injury in sports teams decreases player performance as well as player availability. Therefore, one of the most important aspects of sports team management is the avoidance and management of injuries in the players in order to maximise player efficiency and availability. The physical demands placed on elite athletes continue to increase with larger training loads and higher frequency of matches or competitions with smaller windows for rest and recovery (Soligard et al., 2016). This high demand placed on athletes increases their risk of injury and emphasises the need of training workload management to decrease that risk (Hulin et al., 2016). However, no single marker of athlete readiness has been shown to elevate the risk of injury/overtraining which is why a multifactorial approach to workload management is ideal (Schwellnus et al., 2016; Soligard et al., 2016). Furthermore, optimal workload is a constantly moving target and therefore requires constant evaluation and managing (Gazzano & Gabbett, 2017).

<u>The acute:chronic workload ratio (ACWR)</u>

Banister et al. (1975) first proposed the concept of ACWR. Acute workload refers to the training load placed on the athlete in the preceding week, known as the ‘fatigue’ state, while the chronic workload refers to the training load of the preceding three to six weeks and is known as ‘fitness’ state (Banister et al., 1975). The comparison of the acute to the chronic workload was theorised to give an indication of the readiness of the athlete for competition workloads as it considers both the positive along with the negative adaptations associated with training. A high chronic workload and a simultaneously low acute workload indicate a well-prepared state of fitness in the athlete, resulting in a ratio nearing 1. Conversely, a low chronic workload and a high acute workload with a ratio which exceeds 1 indicates a fatigued state (Hulin et al., 2014). It was theorised that an athlete in a fatigued state is more at risk for injury as he or she is currently experiencing a higher training load than what they have been accustomed to. The first study to attempt to prove this theory was conducted by Hulin et al. (2014) on cricket fast bowlers. The study found that in the event of acute external workload being similar to or lower than chronic workload the risk of injury in the fast bowlers increased for the following seven days, however no association was found between internal workload (neither acute nor chronic) and injury. Furthermore, when the ACWR was ≥1.5, an increased risk of injury was observed in the following seven days (Hulin et al., 2014). This study initiated the start of multiple studies investigating the association between ACWR and injury risk in a range of different sports. It was found that rugby players with a high chronic workload had a higher resistance to injury than those with a moderate-low to moderate-high

ACWR (ACWR = 0.85–1.35) (Hulin et al., 2016). A similar study in elite young football players found that non-contact injury was significantly increased when the player had a high acute workload and when chronic workload was low (i.e. when the ACWR was >2) (Bowen et al., 2020). It is evident in the literature than different ‘sweet spots’ within the range of the ACWR are optimal for avoiding injury in different sports therefore, there is a need for studies of every sport to determine the association between ACWR and injury risk. The generally accepted ‘sweet spot’ is considered to be between 0.8–1.3 and any ratio above 1.5 is referred to as the ‘danger zone’ (Gabbett, 2016). In soccer the ‘sweet spot’ was found to be between 1.00–1.25 (Malone et al., 2017) while, in rugby, it was found to be between 0.85–1.35 (Hulin et al., 2016). Furthermore, studies investigating the association between ACWR and incidence of injury have been conducted on Australian football players (Colby et al., 2017), rugby players (Hulin et al., 2016), soccer players (Malone et al., 2017) and Gaelic football players (Malone et al., 2016), but there is a lack of studies on hockey players.

The calculation of the ACWR

The ACWR can be calculated using two models. The first being the rolling averages model which is the absolute acute to chronic workload (White, 2017). This model suggests that each workload is equal in effect and considers the relationship between load and injury to be linear. This model does not account for the decay in fitness with time, therefore it is not the most accurate model. The exponentially weighted moving average (EWMA) model accounts for the decay in fitness. This model places a greater emphasis on the most recent workload and assigns a decreasing weighing to older workloads (Murray et al., 2017). It is specifically designed to account for the decaying nature of fitness and the non-linear relationship between injury occurrence and workload. For these reasons, this model is more sensitive in detecting injury risk (White, 2017) and is advantageous to use when managing the workload of an athlete to prevent injury.

Athlete workload management

The pathway to injury by overuse begins with the internal risk factors of the player (age, neuromuscular control, past injuries etc.), followed by the expose to external risk factors (playing surface, workload, equipment etc.) which incite events whereby biomechanical breakdown and injury can occur. This point of event is where the biomechanical stress exceeds the tolerance of the tissue (Meeuwise, 1994). The occurrence of injury is theorised to be due to poor workload management (Foster et al., 2001; Gabbett, 2016; Soligard et al., 2016) and it is well-accepted that all workload-related injuries are considered avoidable.

Thus, sports science attempts to quantify workload in order to control and monitor workload and minimise injury risk (Halson, 2014; Schwellnus et al., 2016; Soligard et al., 2016). The quantification of workload is a useful skill as it allows the coaches/trainers/managers of sports teams to determine the ‘performance readiness’ of the players and thus decrease risk of injury and maximise player availability and performance (Thorpe, 2018). Exposure to loads through training and competition result in positive and negative adaptations associated with training and the difference between these adaptations is estimated as the athlete’s performance readiness (Banister et al., 1975). The workload an athlete is exposed to during training or match-play can result in undertraining or overtraining, of which both can increase or decrease the player’s risk of injury (Orchard, 2012; Gabbett, 2020).

While workload is a combination of sport and non-sport stressors placed on the athlete (Soligard et al., 2016) therefore it is the cumulative amount of stress placed on an individual. Therefore, when a player is exposed to a high workload over a period of time, there is an increase in the player’s risk of injury (Windt & Gabbett, 2017). The crux of athlete training monitoring is to maximise the positive adaptations associated with high workloads, making the athlete more robust against injury, while minimising negative physiological changes and risk of injury (Gabbett, 2016; Gabbett et al., 2016; Windt & Gabbett, 2017). The athlete’s state of homeostasis is disrupted by training and the optimal adaptations occur during recovery periods of training (Booth & Thomason, 1991; Halson, 2014), Thus, the principal of training theory is to utilise the process of biological adaptations to workload to increase fitness and performance in athletes. An incorrect theory is that workload should at no time increase more than 10% each week. This has been shown to be a guideline rather than a rule coupled with the risk of injury is chronic load dependant (Gabbett, 2020). This concept that high chronic workload is a protective factor against injury is known as the training-injury prevention paradox and works toward chronic and acute workloads being equal (Gabbett, 2016). In the instance that acute workload is much larger than chronic workload (i.e. there is a large sudden increase in workload) there is an increase in injury risk (Piggott, Newton & Mcguigan, 2009; Gabbett, 2016).

<u>Internal and external workload</u>

Workload can be quantified as internal or external workload, where external workload is the physical work performed during training sessions and matches (Gabbett, 2004) and internal workload is the biochemical and biomechanical stress responses associated with training (Soligard et al., 2016). It is vital to consider both internal and external workload, internal workload determines the fitness outcome of the athlete and the training workload is prescribed by use of the external load. Furthermore, the consideration of both loads is encouraged because external load can only partially quantify training given that internal load is specific to each athlete (Hulin et al., 2014). External load is usually measured by use of a GPS as distance travelled during training sessions or matches therefore making it an objective measurement. However, subjective measures have been shown to be more sensitive and consistent than objective measurements in determining acute and chronic changes in workload and how the athlete is responding to the workload (Saw, Main & Gastin, 2016). Thus, the use of internal workload measurements via questionnaires or session rating of perceived exertion (sRPE) allow for training to be monitored specifically for each athlete in a more accurate and individualised manner and are recommended in sports teams (Drew & Finch, 2016). sRPE is a non-invasive method of measuring an athlete's perceived exertion training load (session duration [minutes] x RPE) using either CR-10, CR-100 or 6-20 scales (Foster et al., 2001). Athlete self-reported measures have gained popularity in recent years (Taylor et al., 2012) due to its cost efficiency (no equipment is required) and its validity across a large range of sports, training and competition (Day et al., 2004; Impellizzeri et al., 2004; Gabbett et al., 2016). Furthermore, sRPE does not require knowledge of maximal exercise responses to workload to anchor the monitoring (such as maximum heart rate of the athlete) (Foster et al., 2001). Additionally, the interpretation of sRPE is specific to the sport as well as the individual and therefore may be influenced by specific movements (Bartlett et al., 2017).

Psychological markers of training load

The psychological aspect of player profiles is just as important in team management as is the physical aspect. Psychological markers of training status are useful tools which have an abundance of literature to support them (Saw, Main & Gastin, 2016). Subjective measures of training load have been shown to be more responsive to training load than objective measures, therefore making them ideal for monitoring athletes to maximise performance and limit over-training (Saw, Main & Gastin, 2016). The prescription of training load can be identical for each player in a team however, each player will physically interpret the load differently. Not only does the internal load between players differ (Hulin et al., 2014), but the external stressors they experience individually can also have an effect on their performance. The progression of training to the point of overload is constantly managed in sports teams, therefore the underlying mechanisms by which overtraining occurs have been investigated in attempt to find a single marker. Physiological markers (such as haematological, hormonal, inflammatory and immune parameters as well as cardiovascular responses) have been investigated (Lehmann et al., 1998; Smith, 2000; Petibois et al., 2002; Hug et al., 2003;

Robson, 2003). However the findings from these physiological markers have been inconsistent (Saw, Main & Gastin, 2016), hence the increased emphasis on the use of subjective measures as training markers. Poor wellness scores can indicate under-recovery in athletes, whether it be physical or psychological, and can guide practitioners in adjusting training programs accordingly to decrease risk of injury (Soligard et al., 2016).

Measures of wellness as a tool for athlete workload management

Psychological variables have been theorised to have an influence over injury risk in athletes. These stressors may include negative life events (Johnson & Ivarsson, 2011), daily life stressors (Ivarsson, Johnson & Poglog, 2013) as well as sports related stressors (Brink et al., 2010). Poor wellness scores can indicate under-recovery and can guide the coaches and managers of athletes to adjust their training programs accordingly (Soligard et al., 2016). A small number of subjective wellness questionnaires exist for different purposes, aimed to assess how an athlete is coping with training and there is evidence of their validity and reliability. For example, to measure mood disturbances the Profile of Mood State (POMS) is utilised (McNair, Lorr & Droppleman, 1971), for perceived stress and recovery the recovery stress questionnaire for athletes is available (REST-Q)(Kallus, 1995). The following questionnaires have also been used to monitor recovery: Recovery-Cue (Kellmann, 2002), Athlete Burnout Questionnaire (Raedeke & Smith, 2001), Athlete Distress Questionnaire (Main & Grove, 2009) and the Daily Analysis for Life Demands of Athletes (DALDA) has been implemented to monitor stress (Rushall, 1990). However, many of these questionnaires are considered too lengthy to foster compliance among athletes, especially in a team sport (Twist & Highton, 2012). Thus, to improve compliance and specificity, multiple sports practitioners tend to favour their own customised, shortened questionnaires or forms to monitor the team's training load and performance (Hooper & Mackinnon, 1995; Coutts & Reaburn, 2008; Buchheit et al., 2013; Gastin, Meyer & Robinson, 2013; Thorpe et al., 2016). Especially those relating to perceived levels of muscle soreness, fatigue, sleep quality and mood disturbances (Buchheit et al., 2013; Johnston, Gabbett & Jenkins, 2013; Thorpe et al., 2015). A survey conducted in Australia and New Zealand, including high performance sports practitioners showed that 84% of practitioners used self-reported wellness measures (Taylor et al., 2012). Furthermore, of those 84% of practitioners, 80% of them used customised forms of self-reported wellness for their athletes. Self-developed wellness questionnaires usually utilise Likert scales which have been a commonly applied method of subjective wellness measuring due to its simplicity. Multiple ranges have been successfully utilised in athlete questionnaires, including 1-to-5 (Buchheit et al., 2013; Johnston et al., 2013; Freitas et al., 2014; Govus et al.,

2018) , 1-to-7 (Gallo et al., 2016; Thorpe et al., 2016, 2017; Malone et al., 2018), 1-to-10 (Montgomery et al., 2008; Thornton et al., 2016), and 1-to-9 (Flatt, Hornikel & Esco, 2017). Many 1-to-5 scales are adapted from the original questionnaire developed by Mclean *et al.* (2010).

Use of the ACWR in hockey

Hockey is a ball and stick sport with bouts of high speed running between low speed running or jogging incorporated with changes in direction. Players are required to perform both offensive and defensive gameplay across various speeds (McGuinness et al., 2019). Monitoring of the players' ACWR could lead to improvements in player management and decreased occurrence of injury. However, previous research shows that predicting injury solely by the use of the ACWR is unsuccessful in American football as well as European league soccer players (Delecroix et al., 2018; Mccall, Dupont & Ekstrand, 2018), due to the multifactorial nature of injury (Gabbett, 2020). Hockey uses rolling substitutions, this could complicate the accuracy of the subjective measurements that include the time spent exercising (such as sRPE). The use of wellness scores to determine how physically prepared the athlete is to spend time on the field during match play could be a useful tool for sports practitioners monitoring hockey teams. This tool could guide sports practitioners to substitute players effectively given their level of preparedness to maximise the players' effective game play (Ihsan et al., 2017).

Given the current evidence and knowledge supporting the use of ACWR as an injury predictor in multiple other sports and the lack of knowledge of that in the sport of field hockey, a study is required to focus on these relationships in the context of field hockey. Furthermore, the association between ACWR and wellness has been vastly under researched and requires a larger range of sports to be tested.

CHAPTER 2 – METHODS

2.1 Participants

Fourteen male hockey players ranging between the ages of nineteen and twenty-four, playing for the first team at the University of the Witwatersrand, Johannesburg participated in this study (mean ± SD; weight = 72.77 ± 7.96, height = 174.69 ± 6.08). The original sample group consisted of the entire mens first team (twenty-three players), however those who did not fill out the self-reported wellness and training questionnaires adequality (80% completion rate) were excluded from the study. Prior to data collection the players provided written informed consent form stating that their anonymous wellness and performance data may be used for research in this study (Appendix A).

2.2 Study design

This study was a prospective, longitudinal, cohort, correlational study. Each player was asked to fill out a Google form (sent via a link to their mobile phone) at the end of every training/exercise session/match and it was part of the team's monitoring practices. The forms were filled in within thirty minutes post-activity and did not take them more than two minutes to complete. The Google form included an RPE for the session (on a scale from 1 to 10, 10 being the maximal exertion and 1 being rest), the type of physical activity the session was (training, match, gym or other), the duration of the session in minutes and a wellness questionnaire including five wellness scores (fatigue, sleep quality, general muscle soreness, stress level and mood) on a Likert scale from 1 to 5(Appendix B).

2.3 Data collection

Data was collected for a period of 10 weeks during the in-season phase of the premiere hockey league 2019 season.

sRPE

The sRPE was part of the Google form filled out by the players after each training session. It was later compared to wellness scores to determine if an association existed between the sRPE and each individual wellness score.

Quantifying the ACWR

Workload was defined as the RPE multiplied by the session duration in minutes (arbitrary units x minutes). The measurement of ACWR had been validated as a workload management tool in previous research (Gabbett, 2016) . Acute (1 week) and chronic (4 weeks) workloads were calculated using the EWMA model to describe the ACWRs of premier league, male hockey players. This model places a greater emphasis on the athlete's most recent workload and a decreased weighting to older workload (Murray et al., 2017).The ACWR was then calculated as the ratio of the acute workload calculation divided by the chronic workload calculation. The ACWR was calculated for each player daily, using the reported workload of the players and continuously monitored until the point of injury.

Self-reported wellness

The general wellbeing of players was quantified by use of a wellness questionnaire (Gastin, Meyer & Robinson, 2013). Players filled in the questionnaire using a 1-to-5 Likert scale to rate their fatigue, sleep quality, general muscle soreness, stress level and mood where 1 rated poor and 5 rated as very good. The z-scores of wellness scores were separately calculated and analysed to determine the degree of week to week changes in the athletes' responses [z-score = (current rating – baseline rating)/standard deviation].

Definition of injury

Injury records were kept by the team's conditioning coach and injuries treated by the team's physiotherapist. An injury was defined as any non-contact time-loss injury which prevented the player from competing or training with the rest of the team. Injuries included both acute and overuse injuries and those that were not related to training were excluded. The intention was to compare the presence of injury to the current ACWR of the player to determine if a relationship existed between the two.

2.4 Statistical analysis

Data was categorised into weekly blocks from Monday to Sunday. The dependant variables (ACWR and sRPE) were log transformed before the statistical analysis using the mixed effects model to determine the percentage increase/decrease in relation to a unit increase in the independent variable (wellness scores). The relationship between log transformed ACWR and wellness scores, as well as the relationship between log transformed sRPE and wellness scores was analysed using linear with mixed effects regression in STATA (v16). A p value less than 0.05 was considered significant.

2.5 Ethical considerations

Ethical clearance was obtained from the Human Ethics Committee of the University of the Witwatersrand (Appendix B).The players received anonymity in this project by being referred to as P01, P02 etc. and only the head researcher, supervisor and team coaches had access to the players' identities. The raw data and results were password protected on a shared worksheet only accessible to head researcher, supervisor, and team coaches.

CHAPTER 3 – RESULTS

3.1 ACWR and injury

The ACWR of the players during the season showed a mean ACWR ranging from 0.67 to 1.89 (*Table 1*). This study could not comment on the association between ACWR and injury incidence since no injuries were reported during the period of the study.

3.2 ACWR and wellness scores

Linear mixed-effects regression model estimates describing the relationship between the log(ACWR) and each of the five wellness score parameters are shown in *Table 2*. ACWR was negatively associated with general muscle soreness and a unit increase in general muscle soreness showed an 18.3% decrease in ACWR (coefficent: -0.183, CI: -0.324, -0.043, p=0.01)(*Table 2*). A unit increase in fatigue showed a 4.1% decrease in ACWR (coefficent: -0.041, CI: -0.182, 0.09, p=0.561), a unit increase in sleep quality showed a 5.7% decrease in ACWR (coefficent: -0.057, CI: -0.185, 0.071, p=0.386), a unit increase in mood showed a 4.9% decrease in ACWR (coefficent: 0.049, CI: -0.89, 0.186, p=0.49) and a unit increase in stress level resulted in a 3.9% decrease in ACWR (coefficent: -0.39, CI: -0.085, 0.162, p=0.54)(*Table 2*). There was a significant association between the 18.3% decrease in ACWR and general muscle soreness (p=0.01), although all other wellness scores did not have significant relationships with the ACWR (*Table 2*). Furthermore, an increase in weeks of training showed a reduction in the ACWR ranging from 2.4%-2.7% every week, controlling for the different parameters (fatigue, sleep quality, general muscle soreness, stress and mood)(*Table 2*). *Figure 1* provides visual representation of the weekly load fluctuations and the athletes' wellness score responses. The wellness Z-scores ranged from 0.034-0.480 and appeared to follow the increase and decrease pattern of the weekly training load (*Figure 1*).

3.3 sRPE and wellness scores

Linear mixed-effects regression model estimates describing the relationship between log(sRPE) and the five wellness score parameters are shown in *Table 3*. sRPE was negatively associated with fatigue, sleep quality and general muscle soreness. A unit increase in fatigue showed a 19.3% decrease in sRPE (coefficient: -0.193, CI: -0.326, -0.06, p=0.004), a unit increase in sleep quality showed a 13.21% decrease in sRPE (coefficient: -0.132, CI: -0.255, -0.009, p=0.035), a unit increase in general muscle soreness showed a 28.3% decrease in sRPE (coefficient: -0.283, CI: -0.415, -0.15, p<0.05), a unit increase in mood showed a 9.4% decrease in sRPE (coefficient: -0.094, CI: -0.228, 0.04, p=0.172) and a unit increase in stress level resulted in a 8.9% decrease in sRPE (coefficient: -0.089, CI: -0.21, 0.032, $p=0.15$)(*Table 3*). A significant association was found between fatigue ($p=0.004$), sleep quality ($p=0.035$) and general muscle soreness ($p<0.05$), and sRPE (*Table 3*). However, mood and stress level showed no association with sRPE. Furthermore, an increase in weeks of training showed a 0.6%-1.2% reduction in the sRPE every week, controlling for the five different wellness scores (*Table 3*). *Figure 2* provides visual representation of the weekly load fluctuations and the athletes' wellness score responses. The wellness Z-scores showed to range from 0.034-0.48 and they seem to follow the increase and decrease pattern of the weekly training load (*Figure 2*).

Table 2 ACWR (mean ± SD) and wellness scores (mean ± SD) over the 10-week period of the study (n=14)

Week	ACWR	Fatigue	Sleep quality	General muscle soreness	Stress level	Mood
1	1.89 ± 0.97	2.85 ± 0.56	2.89 ± 0.58	2.72 ± 0.62	2.85 ± 0.98	3.59 ± 0.41
2	0.86 ± 0.53	2.78 ± 0.98	2.93 ± 0.88	3.07 ± 0.71	2.52 ± 0.68	3.43 ± 0.44
3	0.68 ± 0.62	2.60 ± 0.77	3.35 ± 1.05	2.75 ± 0.87	2.40 ± 0.83	3.15 ± 0.84
4	1.01 ± 0.56	2.72 ± 0.72	2.96 ± 0.77	2.68 ± 0.43	2.60 ± 0.60	3.29 ± 0.60
5	0.99 ± 0.61	2.62 ± 0.62	2.79 ± 0.90	2.71 ± 0.76	2.73 ± 0.79	3.30 ± 0.97
6	0.67 ± 0.46	2.61 ± 0.81	3.33 ± 0.91	2.46 ± 0.65	2.83 ± 0.94	3.22 ± 0.79
7	1.01 ± 0.51	2.81 ± 0.69	3.22 ± 0.85	3.06 ± 0.56	2.51 ± 0.64	2.93 ± 0.90
8	1.14 ± 0.40	2.67 ± 0.51	2.89 ± 0.76	2.74 ± 0.46	2.35 ± 0.57	2.96 ± 0.73
9	1.12 ± 0.36	2.83 ± 0.33	3.02 ± 0.74	2.79 ± 0.58	2.98 ± 0.74	3.65 ± 0.71
10	0.94 ± 0.38	3.00 ± 0.00	2.89 ± 0.68	2.56 ± 0.42	3.39 ± 0.55	3.39 ± 0.28

Table 2 Linear Mixed-Model Parameter Estimated and 95% CIs for the Relationship Between ACWR and Subjective Wellness Scores (n=14)

Fixed effect	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**p**
	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	
Fatigue	-0.041 [-0.182, 0.09]					0.561
Sleep quality		-0.057 [-0.185,0.071]				0.386
General muscle soreness			-0.183 [-0.324, -0.043]			0.010*
Stress level				0.039 [-0.085, 0.162]		0.540
Mood					0.049 [-0.089, 0.186]	0.490
Week	-0.026 [-0.058,0.005]	-0.025 [-0.057, 0.007]	-0.027 [-0.058, 0.003]	-0.026 [-0.058, 0.005]	-0.024 [-0.057, 0.007]	

Week – the change of ACWR from one week to the next

*p<0.05

Table 3 Linear Mixed-Model Parameter Estimated and 95% CIs for the Relationship Between sRPE and Subjective Wellness Scores (n=14)

Fixed effect	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**p**
	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	Coeff est [95% CI]	
Fatigue	-0.193 [-0.326, -0.060]					0.004*
Sleep quality		-0.132 [-0.255, -0.009]				0.035*
General muscle soreness			-0.283 [-0.415, -0.150]			0.000*
Stress level				-0.089 [-0.210, 0.032]		0.150
Mood					-0.094 [-0.228, 0.040]	0.172
Week	-0.010 [-0.04, 0.019]	-0.006 [-0.037, 0.025]	-0.011 [-0.042, 0.020]	-0.008 [-.039, 0.022]	-0.012 [-0.044, 0.019]	

Week – the change of sRPE from one week to the next

*p<0.05

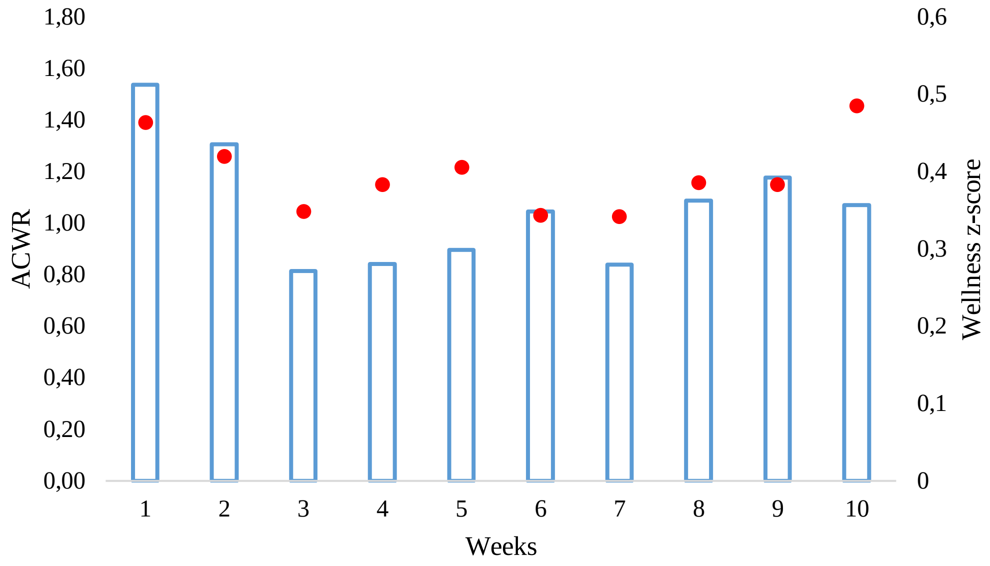

Figure 1 ACWR and wellness z-scores over a training cycle of 10 weeks. Blue bars represent average ACWR of the specified week of all the players and red dots represent wellness z-scores [z-score = (current score – average)/standard deviation]

ACWR - acute:chronic workload ratio

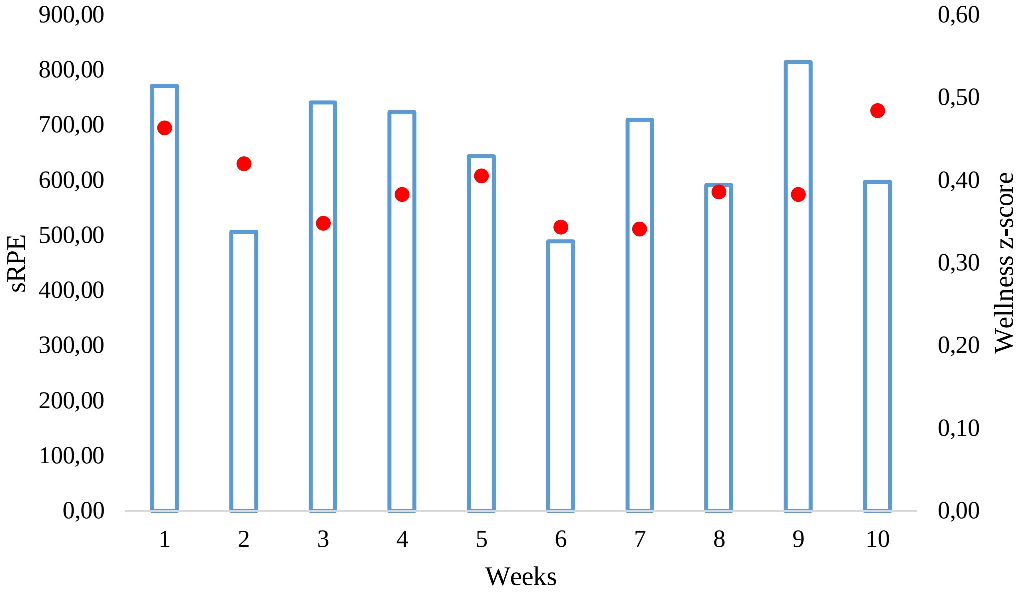

Figure 2 sRPE and wellness z-scores over a training cycle of 10 weeks. Blue bars represent average sRPE of the specified week of all the players and red dots represent wellness z-scores [z-score = (current score – average)/standard deviation]

sRPE - session rating of perceived exertion

CHAPTER 4 – DISCUSSION

This study investigated the relationship between the ACWR and the incidence of injury in male, premiere league hockey players. In addition, the relationship between wellness scores (fatigue, sleep quality, general muscle soreness, stress level and mood) and the ACWR and wellness scores and sRPE was analysed.

The average ACWR reported for all the players during the study period ranged from 0.67 to 1.89. There were no injuries reported during the study period. This may indicate that such ACWRs for hockey players are acceptable with respect to workload management, however this needs to be further investigated because this study could not do any analysis on the association for ACWR and injury incidence.

The ACWR range found in this study is larger than that reported in other studies. Research has determined a 'sweet spot' range for the ACWR of 0.8 to 1.3, within which injury is unlikely to occur due to overload or undertraining (Gabbett, 2016). In addition, any ACWR above 1.5 is considered the 'danger zone' (Gabbett, 2016). A study on professional soccer players found this 'sweet spot' to be between 1.00 and 1.25 (Malone et al., 2017), another study discovered it to be between 0.85 and 1.35 in elite rugby players (Hulin et al., 2016) and a separate study investigating Gaelic football players found it to be between 1.35 and 1.5 (Malone et al., 2016).

A possible explanation for the reported greater range for ACWR in this study, could be due to the different nature of sport type (field hockey) investigated. It may be that the ACWR 'sweet spot' for field hockey is differs to other sports and has a wider range. Field hockey utilises the rule of rolling substitutions during matches. These substitutions make it challenging for players to know the exact number of minutes realistically played during the game when reporting it for the calculation of the ACWR. Owing to the duration of the session being part of the ACWR calculation, the reported ACWR may have been skewed because the player did not report the exact duration of the session. However, this would have only applied to matches.

This study also found that the ACWR was only significantly associated to one of the five wellness score measurements. Fatigue, sleep quality, mood and stress levels showed no significant association with ACWR, yet general muscle soreness was significantly associated with ACWR. In contrast, the study found that sRPE was significantly associated to fatigue, sleep quality and general muscle soreness, but not with stress levels nor mood (*Table 3*). This may indicate that the player's perception of workload (internal load) may be influenced by fatigue, sleep quality and general muscle soreness. These associations show that subjective wellness scores could be a consideration when prescribing training load to a field hockey player. Furthermore, the differing associations between the two measures (ACWR and sRPE) and wellness scores may indicate that the two measures could be measuring different aspects of player load.

Other studies have also investigated subjective measures (wellness scores) in the context of training, and have collected the measures before the athletes participated in their training session or match (Gastin, Meyer & Robinson, 2013; Gallo et al., 2016; Govus et al., 2018). These studies were conducted with Australian football or American college football and all found pretraining subjective measure may provide useful information to coaches as well as be useful indicators of a player's readiness to train. In this study however, wellness scores (and sRPE) were reported after a training session or match.

Research has also found the sRPE to be a good indicator of internal load in soccer (Impellizzeri et al., 2004) and was theorised to be a good indicator of a player's capacity before a training session as well as being a key determinant in their response to training in American college football (Govus et al., 2018). In addition, Govus et al. (2018) found a 1-unit increase in muscle soreness (meaning the player was feeling less sore) was associated with a 4.4% decrease in sRPE in American college football, but our study found the same unit increase in muscle soreness to be associated with a 18.84% decrease in sRPE. A differences in risk factors between the two sports and individual athletes, likely due to varied physiological capacities and physical demands, could explain the disparity as American football and field hockey are two vastly different sports (Thornton et al., 2017).

Ihsan et al. (2017) also investigated male field hockey players and examined the association between wellness measures (fatigue, muscle soreness, mood state and sleep quality) and match running performance over the course of an international field hockey tournament. The results were normalised for playing time, post-match RPE or both playing time and post-match RPE and the study found that changes in player running performance were better associated to changes in wellness scores when running performance was normalised for both playing time as well as post-match RPE. These findings supported evidence for the use of wellness measures as pre-match tools to assist in managing internal load of hockey players during a tournament.

This study uniquely monitored hockey players over the course of a season and considered wellness scores in addition to ACWRs and sRPE. Although, no competitive data is available for the association of the ACWR and wellness scores, other studies support this study's finding, that certain wellness scores were associated with sRPE (Govus et al., 2018).

Limitations

Hockey is a sport which utilises rolling substitutions throughout the match, therefore this skews the subjective wellness data by players being unsure of how many minutes they realistically spent playing. This results in possibly skewed ACWR measurements and could make it challenging for workload to be accurately quantified using self-reported measures. Furthermore, even though the entire team (twenty-three men) were originally included in the study, only fourteen were analysed in the final report. This lack of consistency and compliance from the players is a constant battle for sports practitioners and limits the accuracy of results due to the smaller sample group. Lastly, a longer period of observation would have been optimal to monitor the players' workloads even through their pretraining season. Pretraining is notoriously rigorous and intense as the players are required to reach peak physical conditions in time for the season and then maintain that peak condition throughout the entire season. The process of the players reaching this level of optimal fitness may add a new level of importance to a study such as this one.

Strengths

The strength and conditioning coach working with us and motivating players to complete the questionnaire and report injuries quickly and accurately. We used the EWMA to calculate the ACWR - not rolling averages, which statistically is a better method. We included training and competition in our analysis, which gave a more complete picture of loading as opposed to analysing only one aspect of training.

Recommendations

Further studies should be conducted on the association between ACWR and injury in outdoor field hockey, across a longer duration (ideally including the pre-season training period), in order to formulate a more accurate estimate of the ACWR 'sweet spot'. It is suggested that subjective measures (internal load) used in this study are investigated in conjunction with external load measures such as distance travelled measured via GPS systems. The inclusion of both subjective and objective is supported by the lack of association between the two measures. This lack of association provides support for the concurrent use of both subjective wellness measures and external objective measures in athlete workload monitoring (Saw, Main & Gastin, 2016).

CHAPTER 5 – CONCLUSION

This study investigated the relationship between ACWR and incidence of injury and the association between the ACWR and the sRPE and the ACWR and wellness scores in premier league male hockey players. No injuries were reported within the reported range for ACWR. Thus, no comment can be made with respect to the association between ACWR and injury incidence. In addition, the ACWR was found to only be significantly associated with the wellness measure of general muscle soreness. The sRPE however, was significantly associated with the wellness measures of fatigue, sleep quality and general muscle soreness. Therefore, there may be some merit in the use of subjective wellness measures as workload management tools in field hockey. Further studies are required to find an optimal ACWR for injury risk reduction and workload management for this sport.

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CHAPTER 7 – APPENDICES

Appendix A – Consent form

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

STUDY INFORMATION DOCUMENT

Study title: Association of the acute:chronic workload ratio and incidence of injury in premier league, male hockey players

Introduction:

Good day, my name is Gabriela Veiga and I am doing research on the 1st team means hockey squad of the University of the Witwatersrand. In this study I want to learn what the association is between the acute:chronic workload ratio and the incidence of injury as well as the association between self-reported wellness and the incidence of injury in a men's hockey team. Similar studies have been conducted on multiple other sports but never on men's hockey, hence the need for this research. If significant associations are found, the acute:chronic workload ratio or the self-reported wellness of a player may be able to be used as a tool for monitoring the risk of injury.

Invitation to Participate:

I am asking you to participate in a research study.

What is involved in the study?

The study is a prospective, cross-sectional, cohort, correlational study which will take place during the 2019 hockey season. You will be asked to complete a Google form at the end of each training session or match which will take less than five minutes to complete. The link for the form will be sent to you on your mobile phones and you will be able to fill out the forms immediately and efficiently. You will be asked to rate your perceived exertion of the session on a scale from 1-10 and you will also rate your general wellbeing on a scale from 1-5.

Risks:

No risks are involved in this study.

Benefits:

If significant data come out of this study then the information obtained will be able to guide your coaches and managers in monitoring your workload in order to optimise your physical fitness and decreasing your risk of injury in the future.

Participation is voluntary

If you do not feel comfortable filling out these questionnaires, you are entitled to refuse to participate in the study.

Confidentiality:

Your answers to your questionnaire will only be known by your conditioning coach, my supervisor and myself. The published work will not include your names or answers and will refer to each of you as Player 1, Player 2, etc..

Contact details:

If you have any questions, please feel free to contact me.

Gabriela.n.veiga@gmail.com

0729820216

Outputs:

The study will produce acute:chronic workload ratios and a self-reported wellness results which may or may not be associated with incidence of injury. You may request to receive your results at the end of the season if you are interested.

Contact details of HREC administrator:

This study has been approved by the Human Research Ethics Committee (medical) of the University of the Witwatersrand, Johannesburg. A principle function of the Committee is to safeguard the rights and dignity of all human subjects who agree to participate in a research project and the integrity of the research.

If you feel the need to report a problem or complaint, please contact the HREC administrator:

Mr Rhulani Mkansi

Rhulani.Mkansi@wits.ac.za

011 717 1252

I ________________________________ consent to the results of my Google form questionnaire to be used in the MSc research of Gabriela Veiga.

________________________ ____________________________

Signature Date

Appendix B – Ethical clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Ms G Veiga
School of Therapeutic Sciences
Centre for Exercise Science and Sport Medicine
Medical School
University

E-mail: gabriela.n.veiga@gmail.com

CC: Supervisor: Dr G Torres <Georgia.Torres@wits.ac.za>
and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2019/08/27

REF: *R14/49*

PROTOCOL NO: M190637 *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *Association of the acute:chronic workload ratio and incidence of injury in premier league male hockey players*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University

MSWorks2000/iain0007/Clearscan.wps

Appendix C – Google form

Workload Monitoring

On a scale of 0-10, rate how intense you found the training session/match to be, and how long (in minutes) you trained/played for.

0= Rest, 1=Very, very easy, 2=Easy, 3=Moderate, 4=Somewhat hard, 5=Hard, 6=* 7=Very hard, 8=* 9=* 10=Maximal.

* Required

1. **sRPE** *

   Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Rest	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Maximal

2. **How long did you train/play for (in minutes, i.e. 60)?** *

3. **Session Type** *

   Mark only one oval.

   - Training
   - Match
   - Gym
   - Other

4. **Which team did you play a match for?** *

   Mark only one oval.

   - 1st Team
   - 2nd team

5. **Name** *

6. **Month** *

Mark only one oval.

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

Wellness

Click the appropriate option under each section

7. **Fatigue** *

5=very fresh, 4=fresh, 3=normal, 2=more tired than normal, 1=always tired

Mark only one oval.

1	2	3	4	5

8. **Sleep Quality** *

5=very restful, 4=good, 3=difficulty falling asleep, 2=restless sleep, 1=insomnia

Mark only one oval.

1	2	3	4	5

9. **General muscle soreness** *

5=feeling great, 4=feeling good, 3=normal, 2=increase in soreness/tightness, 1=very sore

Mark only one oval.

1	2	3	4	5

10. **Stress level** *

5=very relaxed 4=relaxed, 3=normal, 2=feeling stressed, 1=highly stressed

Mark only one oval.

1	2	3	4	5

11. **Mood** *

5=very positive mood, 4=a generally good mood, 3=less interested in others and/or activities than usual, 2=snappiness at team mates/family/coworkers, 1=highly annoyed/irritable/down
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Appendix D – Declaration: Student's contribution to article

Gabriela Vega, student number (1102292) declare that this Dissertation is my own work and that I contributed adequately towards research findings published in the article(s) stated below which are included in my Dissertation

Signature of Student..Date....13/01/2020..........

Name of Primary Supervisor: Dr Georgia Torres

Signature of Primary Supervisor ....Date.......13/01/2020........

Agreement by co-authors: By signing this declaration, the co-authors listed below agree to the use of the article by the student as part of his/her Dissertation. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his/her degree purposes.

Appendix E – Approval of study title

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03 January 2020
Person No: 1102292
PAG

Miss GN Veiga
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Dear Miss Gabriela Veiga

Master of Science in Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *Association of the acute:chronic workload ratio and incidence of injury in premier league, male hockey players* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences