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THE USE OF A COUNTERMOVEMENT JUMP TEST TO MONITOR FATIGUE IN FEMALE SOCCER ATHLETES

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THE USE OF A COUNTERMOVEMENT JUMP TEST TO MONITOR FATIGUE IN FEMALE SOCCER ATHLETES

by

Nik A. Chamberlain

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THE USE OF A COUNTERMOVEMENT JUMP TEST TO MONITOR FATIGUE IN FEMALE SOCCER ATHLETES

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ABSTRACT

Introduction: Athletes strive to perform their best over the course of a season. Acute and chronic fatigue can negatively impact performance. Additionally, affordable and accessible field predictors that measure fatigue are needed to help optimize performance. Until recently, procedures that focused on monitoring fatigue were expensive, time consuming, and may contribute to additional fatigue. Lengthy, invasive, and fatiguing procedures are not practical for coaches who do not have the resources to perform complicated measures regularly. Field tests that are quick, non-invasive, and non-fatiguing are ideal for coaches testing athletes at all levels, ages, and genders. **Purpose:** The aim of this study is to determine whether jump tests can be used as a valid tool for measuring fatigue in female collegiate soccer athletes. **Subjects:** Participants consisted of healthy, collegiate-female soccer athletes, aged 18 - 23 (n = 13). **Methods:** Prior to testing, all athletes completed a health questionnaire and an informed consent form to allow participation in the study. Two practice dates were scheduled to provide ecologically-valid testing environments for data collection. During data collection the athletes performed a standard warm-up, and then reported to the testing area to complete the jumping protocol. The jumping protocol consisted of the athletes completing two vertical jumps and two drop jumps. The highest jumps were recorded for analysis. After the pre-practice jumps, athletes participated in their usual practice session. After practice the post-practice jumps were completed in same manner described above. **Results:** A paired sampled *t*-Test revealed differences between the pre-practice vertical jump (0.46 m ± 0.06 m) and post-practice vertical jump (0.45 m ± 0.05 m, $p = 0.05$) and between the pre-practice drop jumps (0.28 m ± 0.04 m) and post-practice drop jumps (0.26 m ± 0.07 m, $p = 0.01$). There was no difference between the time spent on the mat during the drop jump between pre (0.45 secs ± 0.11 secs) and post-practice (0.46 secs ± 0.14 secs, p = 0.27). **Conclusions:** Countermovement jump (CMJ) tests (vertical starting position and drop jump) can be used to monitor fatigue pre- versus post-practice. Further research is needed to elucidate the application of using CMJ's to track team and individual fatigue over a season or off-season.

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CHAPTER 1

THE USE OF A COUNTERMOVEMENT JUMP TEST TO MONITOR FATIGUE IN FEMALE SOCCER ATHLETES

INTRODUCTION

It is vitally important for athletes to maintain optimal performance over the course of a season. If not managed properly, the cumulative physiological load from practice, training, and matches may increase the risk of injury and decrease performance in competitive athletes. Despite the overwhelming evidence supporting the need to monitor fatigue in athletes there is a lack of research investigating affordable and accessible field assessments for team sports. Ideally, a competitive sports team would prefer field tests that are quick, non-invasive, non-fatiguing, and suitable for all levels, ages, and genders.

Soccer is an intermittent sport where the athlete is constantly performing intervals of high- and moderate-intensity movements throughout a match. The nature of the game requires players to produce a combination of explosive and enduring actions such as continuous running, repeated sprints, jumping, changes of direction, and contact with opposing players. Research has indicated that soccer matches induce muscle damage (69) and the frequency of matches and time spent playing determines the amount of muscle damage. During a collegiate soccer season, athletes are required to play with minimal days of recovery, often two games within three days. Increased game frequency can lead to more accumulated fatigue and less recovery periods which contributed to an increase the chance of sustaining an injury (28, 41). For an athlete and team to be successful avoiding injuries is vitally important. Coaches that monitor fatigue in their players can adjust training programs and playing rotations that best reflect the needs of the athlete and team to reduce the risk of injury and maintain optimal performance (41, 60).

Various tools have been used to monitor and athletes fatigue. Halson (23) suggested that there are two different methods of monitoring an athlete. An athlete can be measured by internal and external methods. Examples of internal characteristics that can be measured are the use of questionnaires for an athlete's subjective perception of fatigue. Perception of fatigue can be used as a rating of perceived exertion (RPE) and also a session RPE (23). Coaches can monitor heart rate during exercise (25) and heart rate-perception of effort ratio (25). Training Impulse (TRIMP) is often considered a useful means of assessing training load but requires continuous heart rate monitoring and analysis (25). Blood draws to investigate creatine kinase levels (41, 54) and blood lactate levels can be used but are invasive and require a specific expertise (4). External methods are those that can be measured independently of the athlete's internal characteristics (70). Examples of external methods in team sports include time-motion analysis (TMA), including global positioning system (GPS) tracking and movement pattern analysis via digital video (65). Video analysis allows an athlete to be monitored with every movement they produce during a game and training, how often and the speed of the actions. Another external method is monitoring neuromuscular function with measurements of sprint performance (4), isokinetic and isoinertial dynamometry as well as jump tests (countermovement/squat jump) (66). These assessments have become popular due to the simplicity of administration (a jump mat can be transported wherever it is required), non-evasive to the athlete and the minimal amount of additional fatigue induced. . Recently, studies have investigated professional handball, soccer, and rugby players using the countermovement jump test (CMJ) to monitor fatigue (46, 49, 50, 57). Predominantly, male athletes have been the focus of investigators with very little attention aimed towards women athletes. This study is the first known that will solely focus on CMJ to monitor fatigue. Furthermore, it is also the first to use both a standing and drop CMJ to monitor fatigue. The aim of this study is to investigate the effectiveness of two different CMJ protocols as a tool for monitoring neuromuscular fatigue in female soccer athletes.

METHODS

Subjects

The project was approved by the Auburn University at Montgomery Research and Ethics Committee and all athletes provided consented prior to participating. Thirteen female collegiate soccer players volunteered to participate in the study. Three participated completed one session, while 10 completed two sessions. Athletes scheduled a time when they would enter the Human Performance Laboratory to complete pre-study informed consent, questionnaires, and complete basic anthropometric measurements. The basic anthropometric measurements yielded physical characteristics of the participants were as follows (mean ± SD): age 20 ± 2, body mass 61.5 ± 7.5 kg, height 1.65 m ± 0.06 m and body composition 24.4 ± 5.4 % fat. Body mass was measured using a Tanita BWB-800A Class III weight scale (Arlington Heights, IL, USA), height was measured using a Seca 216 wall mounted stadiometer (Birmingham, UK) and body composition was calculated using Harpenden skinfold caliper (Baty International, West Sussex, UK) and the taken of three sites (Triceps, Suprailiac and Thigh (48))

Procedures

Athletes performed a practice round of countermovement jumps (CMJ) to familiarize themselves with the procedures. Athletes were instructed on how to complete both types of CMJs. The first jump was from a standing positon using the hand held computer and jumping mat. Athletes were instructed how each countermovement jump was to be completed (i.e., feet comfortable distance apart, countermovement, arm swing). Athletes were also instructed to land on two feet and safely bend their knees upon impact with the ground. The box drop jump required the athlete to stand on a plyometric jumping box from a height of 0.51m. The athlete was instructed of out to dismount the box with a single-foot step before landing on two and mimicking the standing jump thereafter. The athletes jumped when they felt ready and were asked to put maximal effort into each jump. Vertical distance was measured by a handheld computer and companion mat commercially available that measures height based on air time (Just Jump or Sonic Timer, Probotics Inc. Huntsville, Alabama, USA) and the plyometric box is commercially available (Detonate 3-in-1 Plyobox, GOPHER Performance).

Data collection sessions were performed at a later date at the practice location. The CMJ's were performed on a hard surface providing a hard, stable jumping surface. Data collection sessions took place on two different practice days. Of the 13 participants that consented, only 10 completed both days of testing. There were no differences in the results between days, therefore all pre-data and post-data were combined. Prior to each jump athletes were instructed to remove their cleats to avoid the potential of slipping on the plastic mat. The standing vertical jump was completed before the drop jump. Each jump was completed twice and the best effort was used for analysis. Prior to the pre-practice jumps, athletes underwent their normal warm-up routine which consisted of a cardiovascular warm-up and a series of dynamic and static stretching. Following the cessation of the practice session athletes immediately returned to the testing area to participate in their post-practice jumps which followed the same protocol as the pre-practice jumps. All data points where recorded but only the highest value in each variable was used for the results. The practice sessions on which data collection took place were similar. Day 1 included a 4 verses 2 possession game in a tight square, followed by a technical session that included passing and shooting. This was followed by a transitional game between attack and defense which included shooting, this game was intense due to the flowing nature and the constant changing between attack and defense. The session finished with small sided games on a relatively large field. The second session was undertaken indoors and again started with the 4 verses 2 possession game. Following that, were two 15 minute games and one 20 minute game played in an indoor arena where the ball never leaves the field of play so the intensity of the session was high.

Statistical Analysis

All data was collected in inches but later converted to meters. The highest jump value data point was used from and reported as a mean ± SD. A paired sample *t*-Test was used to investigate mean differences in the pre- versus post values. Variables used for the paired-samples-test were comparison PreVJ and PostVJ, PreDJ and PostDJ, and PreMat and PostMat. For all statistical tests, the level of significance was set to $p = \leq 0.05$. Microsoft Excel 2010 was used to calculate for the calculations above. Pre-jump tests reliability was assessed using Intraclass Correlation Coefficient using SPSS 21.0 (IBM

Corp., Armonk NY, USA). Pre-practice jumps and post-practice jumps were strongly reliable; ICCR = 0.970 and 0.984 respectively.

RESULTS

Paired-samples *t*-Tests revealed differences between the PreVJ (0.46 m ± 0.06 m) and PostVJ (0.45 m ± 0.05 m, $p = 0.045$). Additionally, the PreDJ (0.28 m ± 0.04 m) and PostDJ (0.26 m ± 0.06 m, $p = 0.010$). There was no difference between the time spent on the mat PreMat (0.45 secs ± 0.11 secs) and PostMat (0.46 secs ± 0.14 secs, $p = 0.27$).

DISCUSSION

Currently, few studies have used a CMJ test as part of a battery of testing to monitor fatigue (2, 47, 63) within female soccer athletes. Females have different vertical jump profiles relative to their male counterparts due to muscle size, force production, connective tissue properties, and body composition differences. At present, this is the only known study that has focused purely on solely using a CMJ test to monitor fatigue in females. Furthermore, it is the only study that has used a drop jump and thus the only study that used both in combination. The results of this study provide further evidence that meaningful changes VJ and DJ performance is acutely lowered in an ecologically valid setting within collegiate, female soccer athletes. This supports results from other studies with soccer players and other intermittent sports (i.e., basketball, handball, hockey and rugby) that also found CMJ was a good tool to monitor fatigue (28, 29, 32, 41, 49, 50, 55, 56). Results from these studies show CMJ performance was acutely lowered after a games or practices when compared to their jumps pre-practice or game. Previous studies that have used drop jump tests within soccer have found similar results. One study used a drop jump test on male soccer players throughout stages of the collegiate season (57), another also used a drop jump test on elite male soccer youth players and found positive results for monitoring fatigue (24). However, these findings contradict reported results that found no significant difference in CMJ before and after practice in elite youth soccer players (36). Limitations experienced during Malone's (36) this study were a small sample size (n=9) due to the lack of availability of elite level subject, this may have affected the statistical significance for some of the findings. Another limitation was only one week was selected out the season and although the practice sessions represented a "typical" in season weekly microcycle, depending on the schedule of games and what the focus of the practice session may have been, the workload of the players may have been low which would have affected jump test results as they may have only had a tactical session where the demand of the players would have been lower when compared to a fitness session

Due to the nature of soccer, prolonged high intensity intermittent exercise produces a rapid amount of free radicals within the mitochondria of the cell which (11) found that free radicals can damage key contractile proteins including myosin and troponin. One study found that damage to these proteins can limit the number of myosin cross-bridges in the strong binding state and reduce the calcium sensitivity of myofilaments (64). Another found that high radical production can depress sodium and potassium pump activity in the working skeletal muscles (40). Free radicals are molecules that have an unpaired electron in their outer orbital, which makes them highly reactive. That is, free radicals quickly react with other molecules in the cell, and this combination results in damage to the molecule combining with the radical. Recent evidence that compared with type I fibers, type II skeletal muscle fibers possess unique properties that promote mitochondrial ROS production (51). A recent study reported that mitochondrial ROS leak (i.e., H2O2 release/ O2 consumed) was two- to threefold greater in type II fibers compared with type I (1). Therefore, the use of a CMJ test would be a good indicator to monitor fatigue due to the explosiveness of the movement.

Several limitations were experienced during this study. One such limitation was the amount of sessions where data was collected; multiple sessions would have given a better representation of monitoring fatigue over time. Future work should look at more practice sessions as well as games and over a period of time with the workloads of the training sessions noted. Noting the workloads of practice sessions may have an effect on CMJ performance as a fitness session during a break of ten days before the next game will have an increasingly higher workload on the athlete than a tactical walkthrough session the day before a game. Furthermore researchers must also investigate if either of the jump tests used in this study may be more suitable for different applications.

In conclusion the results in this study support using CMJ to monitor fatigue within female soccer practices. This is the first study to use a vertical and a drop jump test. Both tests were sensitive enough to detect fatigue but further research is needed to assess difference between vertical and drop jumps to assess fatigue. Based on the findings in this study both jump tests are a valid tools for monitoring acute fatigue in collegiate female soccer athletes.

CHAPTER 2

REVIEW OF THE LITERATURE

Gibson (20) simply defined fatigue as an inability to maintain a power output or force during repeated muscle contractions. There are a variety of factors that could potentially influence fatigue and these influences can be internally related, for example, the central nervous system function, and diet and energy production. External influences can also influence fatigue, of which could be related to the environment with the weather and/ or playing surfaces being examples. Scientists have found different reasons why fatigue occurs with suggestions that fatigue could be due to the fiber type and training state of the subject, whether the muscle was stimulated voluntarily or electrically, and the intensity and duration of the exercise, and whether it was continuous or intermittent activity (41, 59). Prolonged high intensity intermittent exercise produces a rapid amount of free radicals within the mitochondria of the cell which a study found that free radicals can damage key contractile proteins including myosin and troponin (11). Others found that damage to these proteins can limit the number of myosin cross-bridges in the strong binding state and reduce the calcium sensitivity of myofilaments (64). High radical production can depress sodium and potassium pump activity in the working skeletal muscles (40).

Importance of Recovery

Recovery in sports is a vital area to be able to keep athletes performing at their highest level on a consistent basis. For many years coaches and sport scientists have been trying different techniques and aids to help the athlete recover as quickly possible to be able to train or compete again at a high level of intensity. An article highlighted the importance of optimizing the recovery-stress state in athletes (30). The limits within physiological and psychological dictates a need for research to address the avoidance of overtraining, maximizes recovery, and successfully negotiates that fine line between high and excessive training loads (30). Although most coaches recognize that recovery is crucial within the sport setting, they often have limited knowledge of what recovery modalities and monitoring tools are available (62). More and more coaches are seeking the guidance in designing recovery techniques to maximize training and subsequent performance (73). The professional who administrates the athletes training, needs to make sure that the athlete is in prime condition and testing an athlete to see how recovered they are, is vitally important.

Throughout the years professionals have used a variety of techniques and tools to help the athlete recover from exercise. A brief overview of a variety of methods that could potentially enhance recovery (5), these include; active versus passive, diet, ergogenics and training recovery, rehydration and training recovery, massage therapy, analgesics in training recovery, cryotherapy and training recovery and combined treatments.

Techniques for monitoring fatigue

Research has shown that there are different methods and techniques to help with recovery but they do not monitor the athlete's recovery from fatigue. As mentioned, coaches are seeking guidance from experts in the field to help with techniques in order to help athlete's recovery quicker and to monitor such recovery (73). Along with these findings many sports teams have allowed studies to be performed on their teams to monitor an athlete's fatigue and recovery. This allows for a more individualized recovery program for each athlete. There are accurate measures for assessing an athlete's recovery level but they are usually invasive and require funds and a specific laboratory. One fatigue study, studied markers of post-match fatigue in professional rugby league players, one of these markers were saliva and a blood plasma test (41). From the saliva they looked at salivary cortisol concentrations and from the blood plasma they evaluated plasma creatine kinase concentration. Another performed a similar study looking at baseline differences between testosterone and cortisol in rugby union players and the results that support this method of monitoring fatigue (71). This method allows elite professional sports teams and athletes the chance to use a tool to based aforementioned reasons. It is unlikely that collegiate and amateur coaches will have access to this kind of equipment.

There are many field tools that can be used by coaches that are generally less expensive and not invasive to monitor the individual athlete. One of these tools is a perceived recovery scale (33). This study tested sixteen volunteers (8 men, 8 women) through 4 bouts of high-intensity intermittent sprint exercise before being asked their subjective view on how fatigued and recovered they felt at different periods. What the study found was that the volunteers were able to determine changes in performance based on a perceived recovery scale used to monitor fatigue. This study however refutes the findings of another study (19) that also used a subjective tool to measure and monitor levels of fatigue. Their study used a wellness questionnaire focusing on certain areas that would be affected by those playing elite professional Australian football. Their findings suggest that self-reported wellness ratings questionnaires provided a useful tool to monitor a player's subjective feelings towards fatigue. Both of these studies used subjective tools and asked how an athlete feels; this could be problematic as a psychological assessment may not relate to a physiological assessment.

A physiological tool to monitor fatigue that has been studied is the use of heart rate variability in national level Judo athletes. With athletes undertaking high intensity training that their heart rate variability results showed stress levels from the body which tells the researchers that the body is not in a recovered state and therefore is in a fatigued one (43). Other physiological field tests require the athlete to provide a movement or some level of exertion on the body to monitor fatigue. One of these tests is a maximal repeated-sprint test performed on National Collegiate Athletic Association Division 1 hockey players. One study looked at pre-season and post-season repeated-sprint tests (32). An area they evaluated was fatigue and recovery changes. They found that between the tests there was no change in fatigue and recovery. The sport an athlete plays also determines what kind of movement they would go through to monitor fatigue. Freeston et al. (16) studied elite junior baseball players by assessing their shoulder proprioception, maximal throwing velocity and throwing accuracy. There would be no benefit in testing Baseball player's level of fatigue using a countermovement jump test due to the baseball player's main actions being throwing.

Intermittent sports such as handball, basketball, rugby and soccer are sports that require high intense actions such as jumping, sprinting, quick agility and cutting movements, constant contact with other players as well as short bursts when kicking, throwing, blocking, heading or tackling. CMJ tests are performed quickly and non-evasive to the athlete. Ronglan et al. (55) used a CMJ to test fatigue of the female Norwegian handball team during a 5-day training camp and a 3-day international tournament. CMJ was tested using a force plate with the depth self-selected with the best of 3 jumps used for analysis. This test was selected because it has been shown to be sensitive to small changes in leg-extensor force-generating capacity and to have a very good test–e-test reproducibility (CV<5%) (52, 53). A baseline jump was performed before the first session and following jumps were performed before/ and or immediately after training sessions. At the international tournament a baseline jump was performed at the start of the training camp and then immediately before and immediately after each game. They found that there was a reduction in performance during the training camp (6.9 ± 1.3% ($P < 0.01$)) and during the international tournament play (6.7 ± 1.3% ($P < 0.01$)).

The use of jump mates to measure height has been used consistently since Bosco (7) developed an electronic apparatus that could measure flight time. This apparatus is called "Ergojump" (Junghans GMBH-Schramberg, BRD) and is still used in modern studies; Marina (37) has used the Ergojump in plyometric performances in male and female gymnasts, Vila (68) used the mat to collect anthropometric profile measures of elite handball players and Boone (6) also used the mat to compare jump heights of different player positions in soccer. Also, a quick search on Google Scholar using the phrase "Jump mats to measure height" revealed 25,600 results and when using the phrase "Use of jump mats to monitor fatigue" 11,700 results related to the search phrase was gathered. The search results show that the use of jump mats to measure both jump height and using to monitor fatigue is in vast abundance and has been used many times over the years. The use of the Just Jump Systems mat used within this study was validated by Isaacs (26) when he compared the use of the mat against the Vertec vertical jump test when testing the height of 480 children. More recently a study by Whitmer (72) tested thirty-five healthy college students of both genders with the results showing a high correlation between the Just Jump system and the Vertec with a result of 0.960. The Just Jump system includes a square mat (27 in. by 27 in.) and attached is a handheld computer that equates the results. With the aid of microswitiches embedded in the mat, flight time is measured as the interval between liftoff of the feet from the mat to the landing of the feet back on the mat (9, 17, 18, 21, 35). The computer displays both air time (within one one-hundredth of a second) and the height of the jump (to the nearest half inch) simultaneously, which removes the need for hand calculations. Height is calculated using a formula: height of body center of mass = $(t^2 \times g)/8$ (17, 18, 21). In the equation, g = 9.81 $m \cdot s^{-2}$ and t is the flight time. Leard (34) also tested the validity of the Just Jump System by using thirty-nine college students (n = 39, females = 25 and males = 14) between the ages of 18 and 25. Participants had reflective markers placed at the base of the individual's sacrum for the 3-camera motion analysis system to measure vertical jump height. The subject was then instructed to stand on the Just Jump mat beneath the Vertec and perform the CMJ. The Pearson r statistic between the video and the jump and reach (Vertec) was 0.906. The Pearson r between the video and contact mat (Just Jump) was 0.967. West et al. (71) tested CMJ (also tested cortisol in the saliva and creatine kinase in the blood plasma) on 14 male professional rugby union players. A baseline CMJ was performed 36 hours before a match and at regular intervals following the game at 12, 36 and 60 hours postmatch. 3 maximal effort jumps were performed each time at each of the intervals on a portable force plate. Results showed that peak power output had decreased below baseline at 12 hours ($p = 0.004$; 95% CI = -235 to -606 W; -7 ± 6%) and 36 hours ($p < 0.001$; 95% CI= -223 to -457 W; -6 ± 4%) but was similar at 60 hours ($p = 0.151$; -2 ± 4%). These results were similar to McLellan et al. (41) who used rugby league players and found significant lower jumps 30 minutes after the match ($p = 0.026$), 24 hours postmatch ($p = 0.042$) compared to 30 minutes postmatch. They also found results returning to baseline values 48 hours postmatch.

The use of drop jumps to monitor fatigue have also been used with a Google Scholar search of "Use of drop jumps to monitor fatigue" yielding results of 20,100 studies and papers related to search phrase. Ford (15) used the drop jump (DJ) to test the validity of knee flexion within female athletes and had correlation coefficients of greater than 0.93. Moran (44) used drop jumps to monitor endurance fatigue and found a reliability of 0.98 with jump height. DJ have been used to monitor fatigue due to the possible reduced ability to tolerate impact forces that is thought to lead to an impaired ability to utilize elastic energy, which is also reflected by longer ground contact times and a slower transition from braking to push-off phases with the initial impact force less well absorbed by the tendomuscular system in a fatigued state (22, 31, 45).

Oliver (47) tested the jump performance of ten youth soccer players pre and post a 42 minute soccer-specific exercise. A squat jump, CMJ and DJ were performed on a force platform but height was used as the measuring value. The results found that there were deteriorations across all conditions with a decrease in 3 cm ($s = 2.9$; $P < 0.05$) and 2.3 cm ($s = 1.7$; $P < 0.01$) in the CMJ and DJ respectively which were both high values than the squat jump (1.4 cm, s = 1.6; $P < 0.05$). The possible reductions in muscle activity during the DJ were caused by muscle damage brought about by the soccer specific intermittent exercise undertaken. Such muscle damage could affect the muscle sense organs (8, 14), or the intrafusal fibers themselves (45). Brockett (8) found that eccentric exercise caused changes in the sense of joint position and sense of force production, attributing these changes to muscle damage and disturbance of muscle receptors. It is possible that the requirement of a soccer player to change the pace of their running (sprinting, accelerating and decelerating), jumping, kicking, changes of direction, tackling and other bodily contacts can lead to some muscle damage, particularly within recruited type II muscle fibers, which are more susceptible to muscle damage than type I fibers (14). Any such damage could then be directly related to the reduced muscle activity and performance observed in the drop jump of the study by Oliver (47), Hamilton (24) and this present study.

CMJ have also been used to monitor fatigue in basketball where a drop jump was used to examine performance characteristics and monitor in-season recovery of 14 female NCAA Division-1 basketball players (74). One jump was performed from a height of 30cm onto force plates at three stages throughout pre-season and four stages throughout the season. Significant differences were found throughout the pre-season and in-season showing that the jump height had decreased from the first jump which was performed at the beginning of that particular season cycle to the last jump performed at the end of the season cycle ($p = 0.021$ and $p < 0.001$).

Nedelec et al. (46) used CMJ to study the playing actions and the effects on recovery kinetics after a soccer match. The CMJ testing included 2 jumps on a force platform with the highest of the best jump recorded with a self-selected depth but with hands kept on the hips. Jumps were performed after a standardized warm-up and before the match. Other jumps were taken at 24 hours, 48 hours and 72 hours postmatch. Results showed that jump height (cm) decreased from the reference (39.9 ± 2.2) 24 hours postmatch (36.9 ± 2.9) before slowly rising at 48 hours and 72 hours (37.3 ± 3.4 and 37.4 ± 2.4) respectively. These findings are similar to those found in another study who studied the recovery of high-intensity training sessions in female soccer players (61). After taking the highest jump from the 2 CMJ each player performed they found a decrease in height from baseline (48.8cm ± 7.9) to 24 hours post-practice (46.9cm ± 7.9).

The above studies show that using CMJ can be an effective way to monitor fatigue. Fatigue can be monitored in a variety of different intermittent sports across different parameters such as; immediately before and after games and practices, over a course of a long season or short tournament and use it to see how quickly they can recover to baseline and therefore a rested state. This will aid the coach and fitness professional to monitor and prescribe more accurate recovery measures for the athlete aiding to return to optimal performance.

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GRAPHS, TABLES AND FIGURES

Table 1. – Table to represent CMJ test results pre-practice vertical jump (PreVJ), post-practice vertical jump (PostVJ), pre-practice drop jump (PreDJ) and post-practice drop jump (PostDJ) in height which was measured in meters.

Table 1.

	Height (m)	**Standard Deviation**
PreVJ	0.46*	0.06
PostVJ	0.45*	0.05
PreDJ	0.28*	0.04
PostDJ	0.26*	0.07

* Indicates significance $\alpha \leq 0.05$.

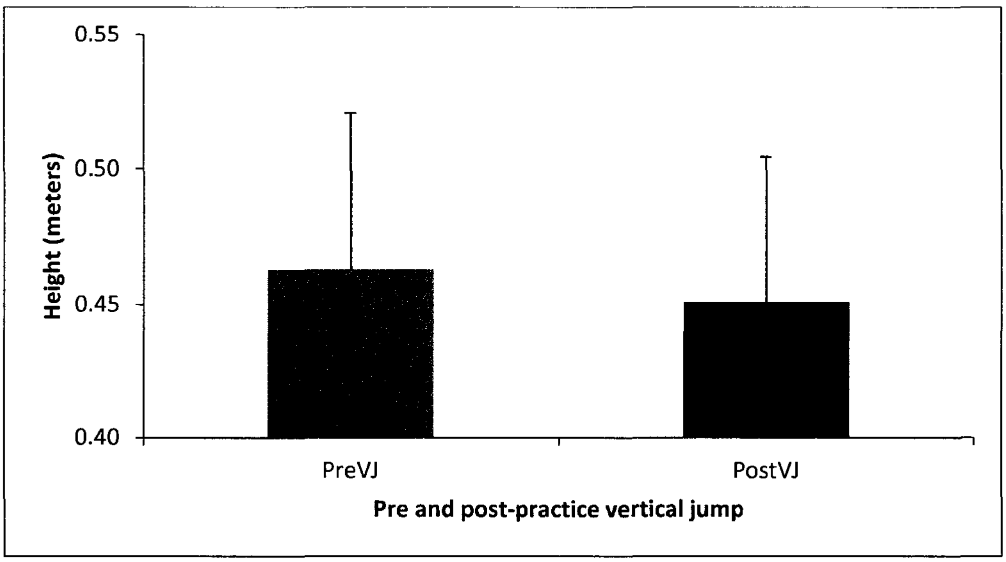
Table 2. – Table to represent the time spent in the air from the vertical jump pre-practice (PreAir) and post-practice (PostAir) measured in seconds. The table also represents time spent on the mat from the drop jump test pre-practice (PreMat) and post-practice (PostMat).

Table 2.

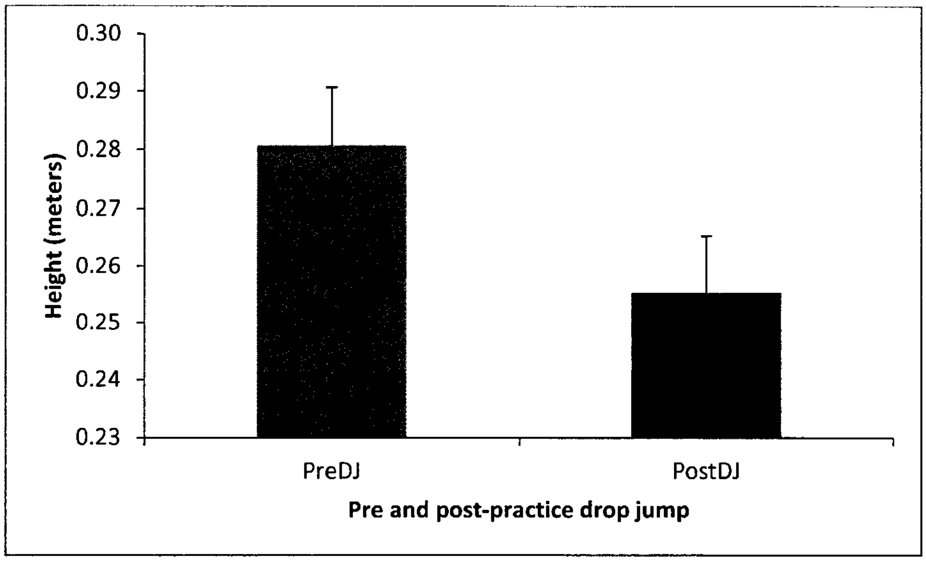
	Time (secs)	**Standard Deviation**
PreAir	0.61*	0.04
PostAir	0.60*	0.04
PreMat	0.45	0.12
PostMat	0.46	0.14

*Indicates significance $\alpha \leq 0.05$.

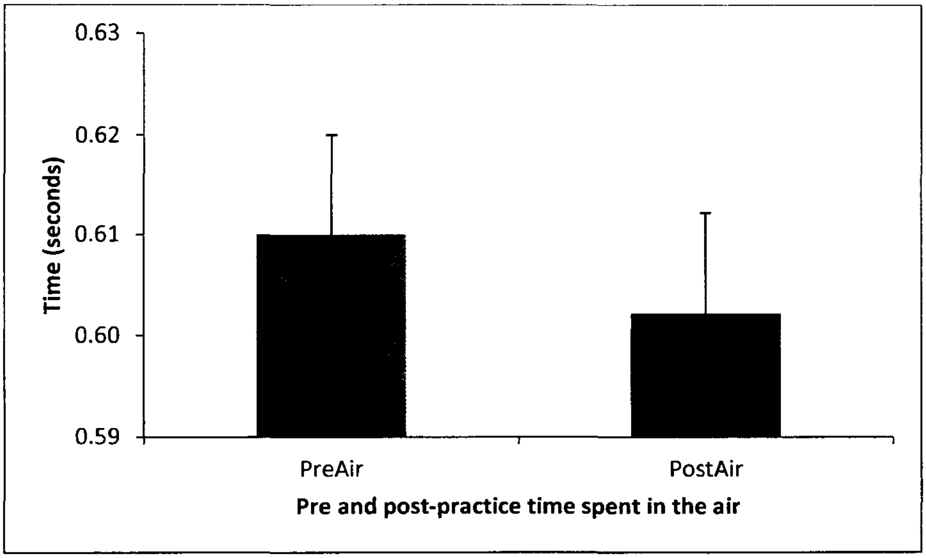
Graph 1. – This graph represents the pre-practice (PreVJ) and post-practice (PostVJ) means and standard deviation results of the standing vertical jump test. The values show a difference between the PreVJ (0.46 m ± 0.06 m) and PostVJ height (0.45 m ± 0.05 m, p = 0.045).



Graph 2. – This graph represents the pre-practice (PreDJ) and post-practice (PostDJ) means and standard deviation results of the drop jump. The values show a difference between the PreDJ (0.28 m ± 0.04 m) and PostDJ height (0.26 m ± 0.06 m, $p = 0.010$).



Graph 3. – This graph represents the pre-pratice (PreAir) and post-practice (PostAir) means and standard deviation results of the amount of time that was spent in the air from the standing vertical jump. The values show a difference between the PreAir (0.61secs ± 0.04 secs) and PostAir time (0.60 secs ± 0.04 secs, $p = 0.044$).



Graph 4. – This graph represents the pre-practice (PreMat) and post-practice (PostMat) means and standard deviation results of the amount of time that was spent on the mat after the initial contact was made during the drop jump. The values show no difference between the PreMat (0.45secs ± 0.11 secs) and PostMat time (0.46 secs ± 0.14 secs, p = 0.277).