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Monitoring Countermovement Jump Performance for Division I Basketball Players over the Competitive Season

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Abstract: The ability to monitor and maintain player readiness and fatigue is paramount to the success of a basketball team over the competitive season. Countermovement jumps (CMJ) are a popular method of quantifying neuromuscular performance and readiness of athletes. Since conference play at the end of the season is when players are needed to perform at their best, a CMJ can also be used to monitor lower body fatigue. Previous research is inconclusive regarding the impact of a competitive season on player fatigue and readiness. The purpose of this investigation was to examine the changes in neuromuscular readiness and lower body power over the duration of a competitive season in male collegiate basketball players. CMJ data of nine collegiate basketball players, who played in all the conference games and conference tournament games, were analyzed. All players were assessed at the beginning of and throughout the season. Players performed CMJs twice each week. A players' best CMJ performance and the preceding jump (so two consecutive jumps) were averaged for this analysis. In addition to jump height, time to take-off, average relative propulsive power, and modified reactive strength index (mRSI) were measured. Players either maintained or improved their vertical jump height over the competitive playing season. There was a significant increase in jump height during the 18-week period of competitive play. There was no statistical change in time to takeoff, over the 18-week period. Although 7 players improved their average relative propulsive power over the competitive season, there was no significant difference statistically. No statistical change was seen for modified reactive strength index. The results of this study did not see a decline in neuromuscular readiness or lower body power over the duration of a competitive season in male collegiate basketball players. Previous studies have reported a decrease in strength and power at the conclusion of the competitive season. Based on results from this study, the ability of the players to produce force quickly was not negatively impacted by games, travel, strength training and practice stress. Monitoring CMJ performance is a valuable method for coaches trying to maintain player's neuromuscular readiness and lower body power during a competitive Division I basketball season.

Keywords: Countermovement Jump, Athlete Monitoring, Neuromuscular Readiness, Lower Body Power, Basketball

1. Introduction

Basketball is a team sport comprised of intermittent high intensity running including accelerations, decelerations and changes of direction [1, 2]. In addition to low, moderate and maximal effort running, players also perform multiple, and often maximal efforts jumps [3, 4].

The basketball season in Division I college basketball in the United States spans four to five months and includes more than 30 competitive games. In addition to games, players participate in daily practice sessions (strength and conditioning sessions, on court individual skill work, on court team practices) and attend academic classes.

The high intensity demands and physiological stress on the players during these 4 to 5 months may accumulate time resulting in fatigue and decreased performance [5]. Strength coaches work to increase players' fitness and muscular power during the pre-season (August – October) until the beginning of the competitive season. Once competitive play begins, the goal is to maintain cardiovascular fitness and muscular power during the competitive playing season [6].

In the United States, scheduled competitive play typically begins in November with non-conference games through December. Conference season play typically starts in January as teams compete for conference titles and the opportunity to play in the national championship tournament. With a focus on competitive play, the frequency of strength and conditioning sessions is reduced which could result in a detraining effect as the competitive season progresses.

The ability to produce large amounts of power for a few seconds is an important physical attribute in basketball. Short, non-fatiguing power tests are useful in quantifying physical preparedness in team sport athletes without creating further unnecessary stress to the players [7]. Countermovement jumps (CMJ) have recently become a popular mode of quantifying neuromuscular performance in team sport athletes [7-9]. A CMJ is a valid [10, 12], reliable [12, 13], non-fatiguing and non-invasive assessment of lower-body power, explosiveness, and neuromuscular fatigue [14-19]. A CMJ, as a neuromuscular marker of performance, has been shown to be sensitive to detecting fatigue in adult rugby league players immediately post-match [20], in the days following a match [7, 21] and over the course of a season in Australian Rules Football [9].

Portable force plates allow coaches to screen CMJ performance outside of the laboratory; thus, coaches are able to screen players more frequently and help improve performance techniques and reduce injury risk [22].

Whitehead [23] found that the physical demands during an ice hockey season resulted in a significant decrease in lower-body power (as measured by a countermovement jump [CMJ]). Other research has also reported an increase in training volume and intensity results in a decrease in lower-body power and CMJ height [18, 19, 24, 25]. However, research with elite youth soccer players reported that there were no changes in CMJ performance during a 4-week in-season training cycle. Additionally, several studies have indicated that performance measures can be maintained during the competitive season [8, 26].

CMJ performance has been used to assess the recovery process of athletes following single and repeated bouts of competition [9, 27]. Other studies have also shown that the CMJ can be used as a longitudinal monitoring tool to identify lower body fatigue [28]. Monitoring CMJ performances not only provides information regarding the recovery from activity but can also provide an indication of the session's volume and intensity to help reduce the risk of injury [27].

Research findings suggest that changes in CMJ performance seen throughout the latter parts of a competitive season may be due to the physical stress associated with an increase in playing time [29]. It has been recommended that monitoring fatigue should be considered over the short and long term [30].

2. Purpose

Despite the time and energy invested to develop the physical fitness for competitive play, there is limited data of the changes in lower body muscular power during the course of a Division I college basketball season. Previous research has found that lower body strength of starters actually decreased despite an in-season maintenance fitness program [31]. Therefore, the purpose of this investigation was to examine the changes in neuromuscular readiness and lower body power over the duration of a Division I competitive season in college basketball players.

3. Participants

For this analysis, nine NCAA Division I scholarship male basketball players were assessed at the beginning of and throughout the competitive season. All players passed the team's mandatory pre-participation physical examination prior to the start of pre-season conditioning. All players gave their informed consent as part of their sport requirements, which is consistent with the institution's policies for use of human subject research.

For this investigation, the de-identified data from the nine players (age = 20.03 ± 1.49 years; height = 189.15 ± 8.51 cm; weight = 84.72 ± 8.06 kg) who played in all of the conference games (N=18) and conference tournament games (N=3) were analyzed. These 9 players included one graduate student, three seniors, three sophomores and two freshmen. Thus, these players accounted for 105 of 105 starting opportunities (5 starters per game, 21 games [18 conference games + 3 conference tournament games]).

All players were assessed at the beginning of and throughout the season. Players completed two strength and conditioning sessions each week. As part of their regular assessment routine (pre-season and in-season), each player completed two to three CMJs during each of the two strength and conditioning sessions (so 4-6 CMJ measurements each week). The CMJs are included in each strength and conditioning session to provide feedback to the coaching staff regarding player fatigue and to assess the impact of their training program on their neuromuscular readiness and lower body power. The last CMJs were performed the week after the last game of the conference tournament.

4. Methods

Neuromuscular readiness and lower body power was assessed with a countermovement jump (CMJ). Each player performed two to three CMJs each session. Players started from an up-right, erect position with hands on the hips. To execute the CMJ, a player flexed their hips, knees and ankles to make the downward squat, or countermovement, to his preferred self-selected position and then immediately jumped vertically for maximum height while maintaining hands on their hips until landing at the same spot on the force plate [32-34].

CMJ without arm swing can be valuable for monitoring and detecting fatigue and overtraining [35]. Previous studies have indicated that arm swings, during takeoff phase, can increase vertical velocity of center of mass as much as 10% [12]. For this reason, to prevent the effect of arm swing and for standardization, participants placed their hands on their hips and kept their hands on their hips until landing on the force plate.

All CMJs were performed after a 10 to 15 minute dynamic warm-up. All CMJ jumps were performed during the first 15 minutes of the training session so that players were appropriately warmed up but not fatigued in order to avoid a detrimental impact on their jump performance. The countermovement jumps were performed on a portable force platform (Hawkin Dynamics), which has been shown to sample three dimensional components of ground reaction force at a frequency at 1000 Hz. The portable force plates used for this investigation have been found to be a valid method for evaluating CMJ performances [22].

Players received immediate feedback from each jump. If a player's second CMJ height was higher than his first jump, he completed a third CMJ. Players were allowed the opportunity to complete additional CMJs until there was no improvement in jump height. Although coaches and players may focus on best performance, it has been reported that tracking changes in performance (individual player or team as a whole) are similar whether using either best or average performances [36]. For this analysis, a players' best CMJ performance and the preceding jump (so two consecutive jumps) were averaged.

In addition to jump height, time to take-off, average relative propulsive power, and modified reactive strength index (mRSI) were measured for analysis. Operational terms for these variables are:

Jump height is the difference in center of mass from take-off and peak positive vertical displacement. Peak positive vertical displacement is calculated using the vertical velocity of the athlete's center of mass at the instant of take-off and the equation of uniform acceleration (TOV^2 / 2G); where TOV is vertical velocity of the center of mass at take-off and G is gravity (9.81m / sec^2)[37]. Jump height was measured in centimeters (higher values are considered better).

Time to takeoff (TOT) is the total amount of time from the initiation of movement to takeoff to the instant of take-off. Time to take off and contact time can be used interchangeably. Time to take-off was measured in seconds (smaller values [quicker times] are considered better).

Average relative propulsive power is the average power (per kilogram of body weight) during the propulsive phase (larger values are considered better). Average relative propulsive power was measured in Watts per kilogram of body weight (W/kg).

Reactive strength index (RSI) and modified reactive strength index (mRSI) are used to assess quickness and reactivity. RSI is the time taken to complete the flight phase (flight time) divided by contact time (the total time taken from the beginning of movement to the instant of take-off); whereas mRSI is jump height (calculated using the vertical velocity of the athlete's center of mass at the instant of take-off) divided by contact time (the total time taken from the initiation of movement to the instant of take-off [time to take-off]). In other words, RSI is flight time divided by contact time whereas mRSI is jump height divided by contact time. For this analysis, we analyzed mRSI.

5. Statistical Analysis

All data are reported as means ± standard deviation unless stated otherwise. Descriptive statistics for the nine players were calculated for age, height, weight, jump height, time to take-off, average relative propulsive power, and modified reactive strength index. Statistical analyses were performed with an a priori significance level of $p \leq 0.05$.

6. Results

Although there were fourteen players on the team, only the data for the nine players who played in all of the conference games (N=18) and conference tournament games (N=3) were analyzed. Physical characteristics and performance measures for the nine players at the beginning of the competitive season were calculated for age, height, weight, jump height (JH), time to take-off (TTO), average relative propulsive power (ARPP), and modified reactive strength index (mRSI; Table 1).

Table 1. *Physical and performance measures at the beginning of the competitive season.*

Players (N=9)	Age (years)	Height (cm)	Weight (kg)	BMI	JH (cm)	TTO (sec.)	ARPP (W/kg)	mRSI
Mean	20.03	189.15	84.72	23.66	44.587	0.749	35.162	0.585
St. Dev.	1.492	8.511	8.060	1.347	2.701	0.060	2.378	0.053

The competitive season for this investigation was 18 weeks and included 34 total games (13 non-conference games, 18 conference games and 3 conference tournament games). In addition to 2 games each week, players also participated in daily practice sessions and attended academic classes. Neuromuscular performance was assessed with a CMJ.

Table 2. *Comparison of pre- and post-season neuromuscular readiness and lower body power.*

	Phase of Season			
	Pre-season	Post-season	p-value	correlation
Body Weight (kg)	84.72 ± 8.06	86.08 ± 8.57	0.0018	0.9953
BMI	23.66 ± 1.34	24.03 ± 1.24	0.0014	0.9836
Jump Height (cm)	44.587 ± 2.70	47.749 ± 3.07	0.0129	0.5664
Time to Take Off (sec.)	0.749 ± 0.06	0.749 ± 0.06	0.5944	0.4958
Average Relative Propulsive Power (W/kg)	35.162 ± 2.37	37.306 ± 1.26	0.0664	0.2642
Modified Reactive Strength Index	0.585 ± 0.05	0.631 ± 0.05	0.1527	0.3203

Values are Mean ± SD

There was a significant change in body weight during the 18 weeks period of competitive play (p = 0.0018). While 2 players maintained their body mass during the competitive playing season, the other seven players experienced an increase in body mass. Figure 1 depicts players' change in mass over the 18-week playing season.

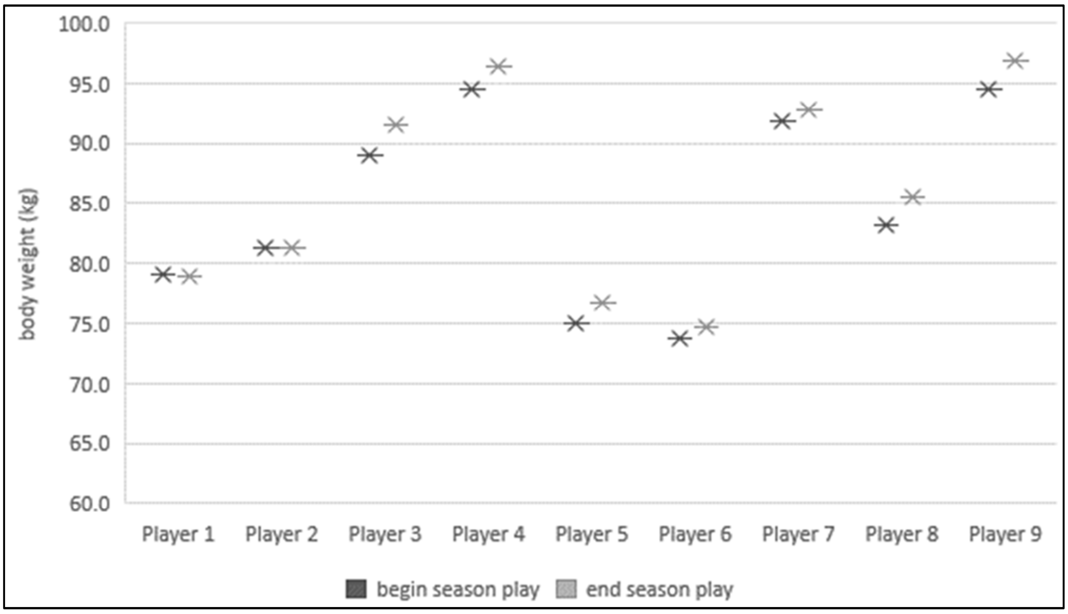

Figure 1. *Change in Body Weight Over the Competitive Season.*

There was a significant increase in jump height during the 18 weeks period of competitive play (p = 0.0012). Players either maintained or improved their vertical jump height over the competitive playing season. Figure 2 depicts players' change in jump height from pre-season to post-season.

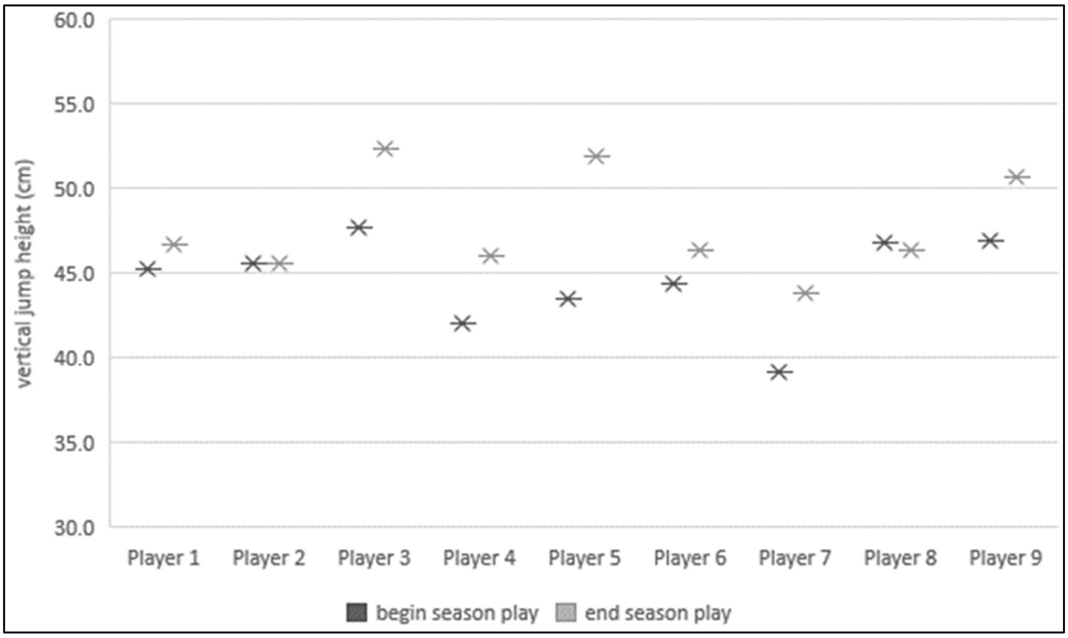

Figure 2. *Change in Vertical Jump Height Over the Competitive Season.*

Time to takeoff is the total amount of time from the initiation of movement to takeoff to the instant of take-off. Four players improved over the course of the competitive season while four players experienced a decrease in TOT. One player's TOT remained unchanged. Thus, there was no statistical change in TOT over the 18 weeks period of competitive play (p = 0.5944). Change in a player's time to takeoff from pre-season to post-season is seen in Figure 3.

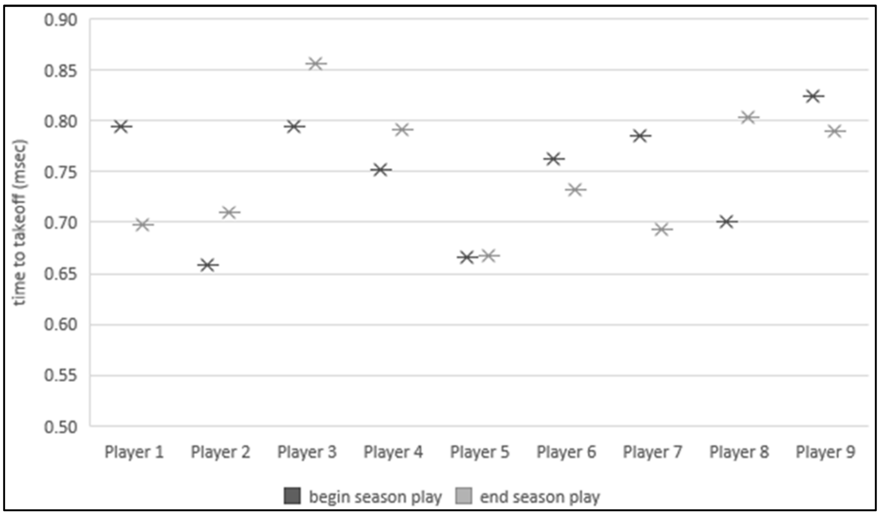

Figure 3. *Change in Time to Take-Off Over the Competitive Season.*

Although 7 players improved in their average relative propulsive power (average power [per kilogram of body weight]) during the propulsive phase of the CMJ) over the competitive season, there was no significant difference statistically (p=0.0664). Changes in average relative propulsive power are seen in Figure 4.

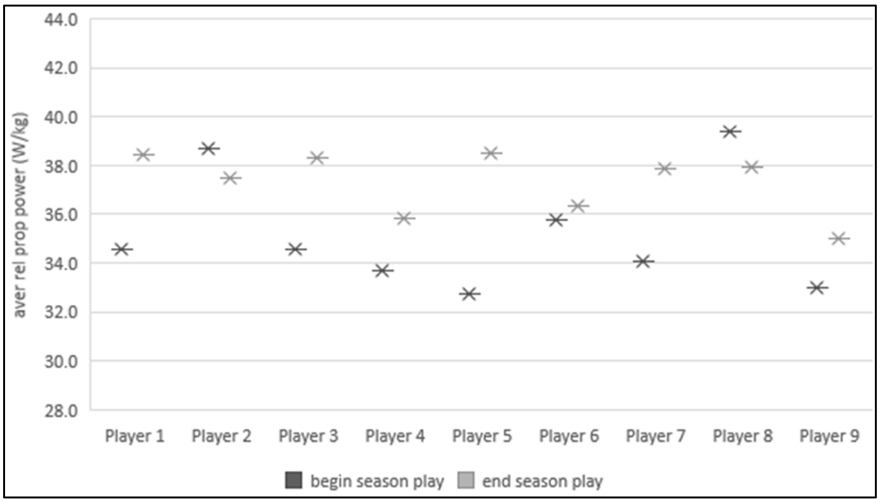

Figure 4. *Average Relative Propulsive Power Over the Competitive Season.*

No statistical change was calculated (p=0.1527) for modified reactive strength index (mRSI). Six players improved while 3 players experienced a decline in mRSI. The changes in mRSI for the 9 players can be seen in Figure 5.

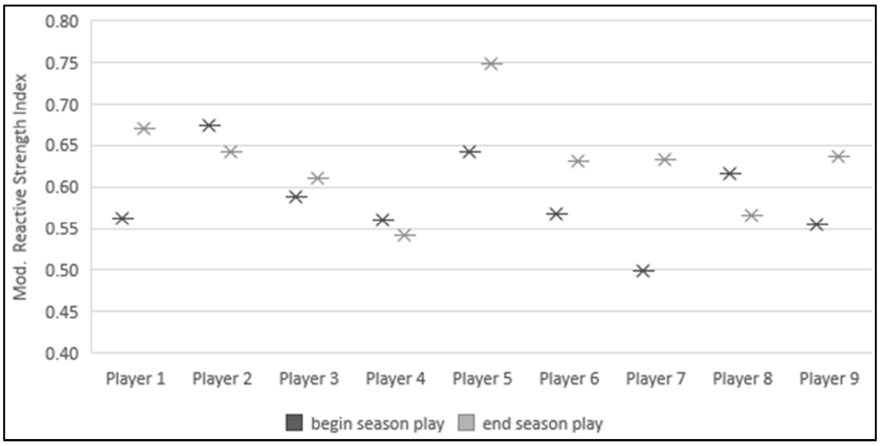

Figure 5. *Change in Modified Reactive Strength Index (mRSI) Over the Competitive Season.*

7. Discussion

During the competitive season, the frequency of strength and conditioning sessions is typically reduced. Previous research has reported that lower body strength of basketball players decreases during the playing season despite efforts to maintenance fitness, strength and power [31]. Coaches often aim to get their players at optimal playing weight and in peak condition prior to the start of the playing season with that perceived inevitable decline in mind. However, the results of this study did not see a decline in neuromuscular readiness and lower body power over the duration of a Division I competitive season in collegiate basketball players.

Coaches often think that the high intensity efforts associated with the competitive season results in a decrease in body mass. Caterisano [31] saw no change in body mass during the competitive season. For this study, the 9 players that played in all 34 competitive games not only maintained their body mass but saw an increase in body mass (average change was +1.37 kg). Bolonchuk [38] reported a slight decrease in fat-free mass over a competitive season. This study did not assess body composition but saw an increase in body mass over the 18-week playing season.

Vertical jump height, assessed by a CMJ, is considered a neuromuscular marker of performance and fatigue. A decline in CMJ performance is typically interpreted as an indicator of fatigue due to the physical stress associated with the high intensity of competitive play. In this investigation, eight of the 9 players improved their vertical jump height from the beginning of the competitive season to the end of the competitive playing season.

Multiple factors, including neuromuscular fatigue, fitness level, and body weight, not only can change during the competitive season but also impact vertical jump height. Kramer [29] suggested that a decline in CMJ performance may be due to a greater amount of physical stress evoked during the competitive season. This study did not support those findings.

From the pre-season to end of the season there was no statistical difference in mRSI for the players. mRSI indicates how much force an athlete is producing and how long it takes them to produce this power; thus, mRSI is used to assess quickness and reactivity. Quickness and reactivity are vital for competitive play; mRSI can also be used to evaluate neuromuscular fatigue and readiness. Results from this investigation indicated that players increased their force production and either maintained or improved their vertical jump height during the 18-week period of competitive play.

mRSI was maintained throughout the 18-week season; in other words, a player's ability to produce force quickly was not impacted negatively by the stress of games, practice, travel, and academics. Maintenance of quickness and reactivity can be interpreted as a positive. Rather than seeing a decline in neuromuscular readiness and lower body power during the competitive season, this investigation indicated that players were able to maintain their quickness and power over the competitive season.

The competitive collegiate basketball season offers many challenges to players (and coaches). As student athletes juggle academics, practice, travel, and competitive play, management of energy and stress (physical and emotional) is crucial. The goal for a team is to perform well during the competitive season in order to win the conference tournament and enter post-season play; thus, peak physical performance from players is needed.

The authors attempted to answer with this study what, if any, changes in neuromuscular readiness and lower body power occurred over the duration of a Division I competitive season in college male basketball players. After evaluating the data gathered with this investigation, strength and conditioning coaches can be confident that college male basketball players can maintain muscular performance characteristics that are needed for competitive play across the duration of the playing season.

It is recommended that future studies monitor body composition during the competitive season to determine changes in lean mass which may provide further insight on changes in jump height performance and lower body power. Studies that monitor and compare external training load during the pre-season to the external training load during the competitive season may further contribute to a better understanding of changes in neuromuscular readiness during the tenure of a collegiate basketball player. It is unknown if there may be a gender difference in changes in neuromuscular readiness and lower body power during the competitive basketball season. A study comparing male and female basketball players' neuromuscular readiness and lower body power during the competitive basketball season is recommended.

8. Conclusion

This study examined the changes in neuromuscular readiness and lower body power over the duration of a Division I competitive season in male college basketball players. In addition to games and practices, players completed CMJ sessions twice each week throughout the competitive season.

Previous studies have reported that a decrease in strength at the conclusion of the competitive season has been attributed to the cumulative fatigue associated with multiple months of competitive play [39]. CMJ can be used as a method for monitoring and detecting fatigue [28, 35]. Monitoring CMJ performances not only provides information regarding the recovery from vigorous physical activity but also provides an indication of training volume and intensity [40].

Although previous research suggested that changes in CMJ performance seen throughout the latter parts of a competitive season may be due to the physical stress associated with an increase in playing time, the results of this study indicated that male college basketball players are able to maintain their vertical jump height over the competitive playing season [29].

Additionally, players were also able to maintain their average relative propulsive power during the propulsive phase of the CMJ).

Monitoring CMJ performance is a reliable and valuable method for coaches trying to maintain their player's neuromuscular readiness and lower body power in male basketball players during a competitive Division I season.

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