Offseason Fitness Tests a Collegiate Basketball Strength Coach Should Choose to Predict In-Season Performance Based on Sex

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Abstract

Quantification of athletic performance via analysis of scores of off-season fitness tests has become an essential part of the modern strength and conditioning coach (SCC). Player Efficiency Rating (PER) and Efficiency index (EFF) are two of the most used in-season basketball performance metrics in the US. We collected data from male and female basketball players of a National Collegiate Athletic Association (NCAA) program. Based on sex, we examined a) if unadjusted PER (uPER) and EFF reflect different amounts of information and b) which fitness tests predict those two indices more accurately. Our results showed lower means and less variability of the fitness tests scores in women than men. The correlation between uPER and EFF in men was moderate and strong in women. In men, no strong correlation was found between any fitness test and EFF, while full court sprint was strongly correlated with uPER. In women, strong correlations were detected between a) the T-drill and EFF and b) the foul court sprint, the vertical jump, and the T-drill and uPER. The collegiate SCCs should consider that off-season scores of a) the foul court drill may predict uPER more accurately in both men and women and b) the T-drill may predict both EFF and uPER more precisely in women.

KEYWORDS: STRENGTH AND CONDITIONING, EFFICIENCY INDEX, SPORTS PERFORMANCE ANALYSIS, PERFORMANCE INDICATOR, NCAA

Introduction

Performance analysis has become an essential tool for coaches, athletes, sports administrators, scouts, and scientists. Collecting and analysing performance information enables all stakeholders to gain a deeper understanding of sports. As a result, more educated decisions and more accurate predictions could be made (e.g., coaches prescribing training programmes for performance and injury prevention) (O'donoghue, 2009).

More specifically, providing feedback, through sports performance analysis on the productivity/output of an athlete/team, constitutes an integral part of coaching (Kim & Cruz, 2016). However, research has shown that observation and memory alone do not provide trustworthy enough information based on which valid inferences can be made (Hughes, Franks, Franks, & Dancs, 2019). Instead, objective measurement is essential for that feedback process. As such, key performance indicators (KPIs)¹ in sports have been identified (Beauchamp, Harvey, & Beauchamp, 2012; Hughes & Bartlett, 2002; Hughes, Franks, Franks, & Dancs, 2019).

KPIs are used extensively by strength and conditioning coaches (SCCs) in the form of offseason battery of tests (Nesser, 2019). Those screening tools are chosen based on the reliability of their scores, the validity of the inferences of those scores, their sensitivity and specificity, but also on needs analysis (e.g., planes of motion, metabolic systems) according to the specifics of each sport (Fleck & Kraemer, 2014). For instance, in basketball, SCCs commonly use fitness tests to assess strength (e.g., 1 repetition maximum bench press) (Levinger et al., 2009; Ploutz-Snyder & Giamis, 2001), speed (e.g., full court sprint) (Simenz, Dugan, & Ebben, 2005), power (e.g., power clean, standing broad jump, vertical jump) (Amonette et al., 2012; Cormie, McBride, & McCaulley, 2009; McBride, Triplett-McBride, Davie, & Newton, 2002; Nesser, 2019) and agility (e.g., T-drill) (Lehnert, Hůlka, Malý, Fohler, & Zahálka, 2013).

The direct goal of this process is a) to quantify the current level of preparedness for competition of the athlete(s) and assess individual and team strengths and areas of improvement (when compared to normative data based on sex, age etc.) and b) evaluate effectiveness of current exercise programmes (e.g., when compared to baseline measurements; Haff & Triplett, 2015). As all the above direct goals are linked to in-season performance, those off-season fitness scores are also used to indirectly predict (i.e. predictive analytics; Siegel, 2013) match performance indicators (MPIs; McGill, Andersen, & Horne, 2012).

Basketball is one of the most popular sport in the world (Shvili, 2020). In the U.S., basketball is one of the most wide-spread sports in high-school (The National Federation of State High School Associations, 2019), collegiate (NCAA, 2021b), and professional levels (Gallup, 2018). In the U.S. professional level, most common MPIs are the Player Efficiency Rating (PER) and Efficiency (EFF) indices (ESPN, 2021; NBA, 2021).

EFF is a linear formula and was developed by Martin Manley, a Kansas City sports reporter (Manley, 1989). It is the player evaluation metric used by the NBA. However, it does not take into consideration the playing time (NBASTuffer, 2021).

$$\text{EFF} = \text{points} + \text{rebounds} + \text{assists} + \text{steals} + \text{blocks} - \text{missed field goals} - \text{missed free throws} - \text{turnovers}$$

PER was developed by ESPN basketball statistician John Hollinger (Hollinger, 2004). PER is a linear regression model and takes into consideration playing minutes, but some argue that it gives undue weight to offensive performance. Unadjusted PER (uPER) is the same as PER, just

¹A KPI is operationally defined as the performance indicator (PI) that is chosen out of all the PIs since it is considered to measure a context-critical objective.

not normalized/adjusted to the pace of play. It has been used in several other studies as an alternative to PER (Baghurst et al., 2021; Zhang, Chen, & Zhao, 2011).

$$\begin{aligned} \text{uPER} = & (1/\text{minutes played}) * [3\text{pointers} + (2/3) * \text{assists} + (2 - \text{factor} * \\ & (\text{team_assists}/\text{team_field goals})) * \text{fieldgoals} + (\text{Free throws} * 0.5 * (1 + (1 - \\ & (\text{team_assists}/\text{team_fieldgoals})) + (2/3) * (\text{team_assists}/\text{team_fieldgoals}))) - \text{VOP} * \\ & \text{turnovers} - \text{VOP} * \text{DRB\%} * (\text{field goals attempted} - \text{field goals made}) - \text{VOP} * \\ & 0.44 * (0.44 + (0.56 * \text{DRB\%}) * (\text{free throws attempted} - \text{free throws made}) + \text{VOP} * \\ & (1 - \text{DRB\%} * (\text{Total rebounds} - \text{offensive rebounds}) + \text{VOP} * \text{DRB\%} * \text{offensive} \\ & \text{rebound} + \text{VOP} * \text{steals} + \text{VOP} * \text{DRB\%} * \text{blocks} - \text{personal fouls} (\text{league_free} \\ & \text{throws}/\text{league_personal fouls}) - 0.44 * (\text{league_free throw attempts}/\text{league_personal} \\ & \text{fouls}) * \text{VOP}], \end{aligned}$$

where VOP = value of possession (in reference to league), DRB = defensive rebounds.

Those mathematical models are used as total performance metrics to determine the “best” athlete per match/week/season. Players with higher MPIs get recruited more and/or get offered better contracts when going professional (Moxley & Towne, 2015). NCAA Division I (DI) student-athletes have higher probability of going pro, compared to other Divisions of college basketball, as the vast majority of professional rosters are filled by DI players (NCAA, 2021a; RPIRatings.com, 2021). Therefore, in their limited-by-NCAA-bylaws time (Simonson, Moffitt, & Lawson, 2014), which fitness tests should a DI basketball SCC administer in offseason (Dreyer, 2005; Papadakis, Stamatis, Padgett, & Sanders, 2019) in order to predict EFF and PER more accurately? In addition, should those batteries of tests be different depending on sex? To our knowledge, this is the first study on U.S. collegiate basketball to a) examine if PER and EFF reflect different amounts of information based on sex and b) offer practical implications to SCCs on which fitness tests may predict those indices more accurately based on sex.

Methods

Data from 18 (male = 10, female = 8; $M_{\text{age}}=20.1$, $SD=1.2$) DI men’s and women’s basketball players from the same university, who participated in off-season testing, were analyzed for this study. To be eligible to participate in this study, participants must have been an active member of the university’s basketball team, injury-free, over the age of 18 years old, and fully participating in the training at the time of enrollment. Additionally, all participants were medically cleared to participate in intercollegiate athletics and read and signed the informed consent forms to participate in this study. Out of the 26 eligible participants, 22 met all criteria and 18 consented to participate in the study.

Instruments

Anthropometric and Body Composition assessments

Height (cm) was measured using the Seca 213 Portable Stadiometer (SECA GMBH & CO, Chino, CA). Weight (kg) was measured using the BodPod (Life Measurement Instrument, Concord, CA), which was calibrated the morning of testing. Participants wore clothes as instructed. Sex and age were self-reported.

Off-season fitness tests

All off-season fitness tests were administered and monitored according to the National Strength and Conditioning Association’s (NSCA) procedures and protocols (Haff & Triplett, 2015) (For more details, please see chapter 12). The SCC performed the following six tests:

- (1) One repetition maximum (1RM) bench press,
- (2) full court sprint,
- (3) power clean,
- (4) standing broad jump,
- (5) vertical jump, and
- (6) the T-drill.

Match Performance Indicators

EFF and uPER were calculated with season match statistics provided by the Athletic Department of the program. These teams competed against teams from more than one conferences. In more detail, by accounting for matches with opponents from other conferences/divisions, those data included more than the teams' conference schedules. Therefore, uPER was preferred.

Procedure

The data were collected during the end of off-season over 4 days (Monday, Wednesday, Friday and Saturday). After following the same warm-up protocol (see Appendix), participants were provided verbal instruction about how to perform each test and were allowed up to two practice trials to familiarize themselves with the tests prior to actual data collection. The order of testing was selected by the SCC, who was certified through NSCA, based on availability of resources, safety of athletes, and efficiency (high level of reliability of scores collected):

- Monday: Bench press
- Wednesday: Power Clean
- Friday: Vertical Jump and Standing Broad Jump
- Saturday: Anthropometrics, body composition, full court spring, T-drill, measures using Optogait (Microgate, Bolzano, Italy).

The data presented in this study were obtained with the permission of the university, athletic department, and athlete to use. This research was carried out in accordance with the recommendations of the declaration of Helsinki and the study was approved for the university's Institutional Review Board (approval #HS2011-2778).

Statistical Analysis

To examine the characteristics of fitness test distributions by sex, the means and standard deviations were generated for each sex. Pearson correlations were estimated as indicators for the relationship between the performance indices and the relationships between each of the fitness tests and the performance indices by sex. Correlations between 0 and $|.3|$ were considered small, between $|.31|$ and $|.5|$ were moderate, and above $|.51|$ were considered strong (Cohen, 1988). We also tested the statistical significance of estimated Pearson correlations using a Type I error rate (α) of .05 against the null hypothesis that $\rho = 0$.

In order to identify any potential patterns within the correlation matrices, each matrix was reordered using hierarchical clustering and then plotted using a heat map for visualization. As a result of this reordering, the patterns of correlations were grouped within the matrix based on the strength and direction of the correlations. This type of data visualization was used to more easily identify which variables were strongly correlated with each other. Negative correlations were colored blue, weak/zero correlations were colored white, and positive correlations were colored red. The deeper the respective hue, the stronger the correlation. No statistical inferences were made due to the nature of the study.

Results

Our results showed lower means and less variability of the fitness tests scores in women than men. The descriptive statistics are shown by sex in Table 1.

Table 1. Descriptive Statistics of Included Variables by Sex.

Fitness Test	Women		Men	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Bench press (lb)	130.0	12.8	248.3	33.2
Power clean (lb)	141.9	16.5	219.4	36.6
Vertical jump (in)	23.3	1.6	29.7	2.5
Standing box jump (cm)	83.0	6.1	109.0	8.6
Full court sprint (sec)	4.8	0.5	4.1	0.2
T-drill (sec)	8.7	0.6	8.2	0.5
EFF (a.u.)	4.9	3.4	8.6	5.9
uPER (a.u.)	-0.0	0.1	0.1	0.1

All values are means $\pm$ SD.

Next, the correlation matrices were examined. Generally, the heat maps are shown in Figure 1. The correlation between uPER and EFF in men was moderate ($r = .36$, $p = .31$) and strong in women ($r = .66$, $p = .04$). Although EFF was not strong correlated with any fitness test in men, it was moderately correlated with standing box jump ($r = .48$, $p = .16$), vertical jump ($r = .36$, $p = .31$), and full court sprint ($r = .36$, $p = .31$). uPER was strongly positively correlated with full court sprint ($r = .74$, $p = .01$), but strongly negatively correlated with bench press ($r = -.62$, $p = .06$) and power clean ($r = -.66$, $p = .04$) in men. In women, EFF had a strong correlation with T-drill ($r = .57$, $p = .14$) and moderate correlation with full court sprint ($r = .38$, $p = .35$). uPER was strongly correlated with full court sprint ($r = .61$, $p = .11$), vertical jump ($r = .66$, $p = .07$), and T-drill ($r = .66$, $p = .07$), and uPER was moderately correlated with power clean ($r = 0.36$, $p = .38$). It should be noted that due to the small sample size any of the above correlations with p values greater than .05 are not statistically significant despite being different from zero in the population.

Figure 1. Heat Maps of Correlations by Sex: (a) Correlations for Male Athletes; (b) Correlations for Female Athletes. Note: the variables are not in the same order on the margins for the correlation heat maps among male and female athletes. All values are means $\pm$ SD. Bench: one repetition maximum (1RM) bench press; Fcsprint: full court sprint; Pclean: power clean; SBJump: standing broad jump; VJ: vertical jump, Tdrill: T-drill.

Discussion

Athletic performance is one of the primary goals of the strength and conditioning professional (Triplett & Chandler, 2017; Waller, Piper, & Miller, 2009). The NCAA training environment is unique though. The scope of practice of collegiate SCCs has expanded and diversified (Triplett & Chandler, 2017), when their time is specified by NCAA Bylaws 17.1.7.1 and 2 (NCAA Division I Manual, 2021; Simonson et al., 2014) whilst they train teams of several sports (Nesser, 2019) with potential in-season adverse training implications (Papadakis et al., 2019). No matter the similarities or the differences between those assigned sports, the collegiate SCCs develop

their testing batteries choosing from established screening/assessment tools (Haff & Triplett, 2015; Nesser, 2019).

In this study, we used off-season scores from six very frequently utilised fitness tests for basketball (i.e., 1RM bench press, full court sprint, power clean, standing broad jump, vertical jump, and the T-drill) and several in-season performance metrics (e.g., rebounds, blocks, assists) from two basketball teams of the same DI program. Then, after calculating uPER and EFF, we examined if these two indices reflect different amounts of in-season performance information per sex. We also investigated if -after controlling for sex- the relationship between those tests and the indices was affected.

Based on the results, we are in the position to offer preliminary evidence on the rationale behind choosing a battery of off-season fitness tests not only based on performance, but also take it a step further: ground it on which of those assessments predict uPER and EFF more accurately based on sex. In more detail, our results showed lower means and less variability of the fitness tests scores in women than men. The former is translated in lower levels of fitness in women, which on average is expected (Haff & Triplett, 2015). The latter has been found before in basketball in higher levels of competition/skill when compared to lower ones (Drinkwater, Hopkins, McKenna, Hunt, & Pyne, 2007; Drinkwater, Pyne, & McKenna, 2008). However, since in our case we are comparing teams of the same level (i.e., NCAA DI), the results infer a greater consistency of fitness scores in the specific roster of the female team.

In addition, no strong correlation was found in men between any fitness test and EFF. There is previous research in basketball exploring the relationship between match performance via EFF and related variables (Staunton, Gordon, Custovic, Stanger, & Kingsley, 2017). However, there is nothing in the literature similar to our investigation to compare our outcomes. In men, only full court sprint was strongly correlated with uPER. Although there is no earlier research to help us reach a deeper understanding of our results, it is clear that there is a strong association between the scores of this specific fitness assessment and uPER in men.

Lastly, in women, strong correlations were detected between a) T-drill and EFF and b) foul court sprint, vertical jump, and T-drill and uPER. Again, in the absence of previous similar research, we can only infer a strong association between the scores of those tests and the indices.

Practical Implications

Basketball is not a sport of certainty (Sarlis & Tjortjijis, 2020). There are several (other than uPER and EFF) MPIs for basketball that are used worldwide (e.g., PIR, PIE, Tendex). This study is not attempting to bring insight on basketball team win forecasting or player impact to the match. It is not focusing on evaluating if uPER and/or EFF are the “best” MPIs, either. Instead, for the first time ever, out of all stakeholders, we are trying to provide suggestions to the collegiate basketball SCC concerning achieving higher levels of efficacy during their time-restricted, off-season fitness testing process. More particularly, we are offering recommendations on the identification of specific off-season assessments/attributes that are the most important for forecasting purposes of in-season performance as captured by uPER and EFF.

Our outcomes suggest that uPER and EFF reflect different amounts of information based on sex. Therefore, although both are widely used as MPIs in U.S. basketball, SCCs should know that athletes of theirs may have different representation in terms of in-season efficiency based on the MPI used. Other practical implications include that a) foul court drill scores may predict uPER more accurately in both men and women and b) T-drill scores may predict both EFF and uPER more precisely in women. In other words, if they had to pick one test for both teams, foul court drill appear as the test with the higher probability to yield the highest return in terms of predicting

uPER. Similarly, if they would want to collect the most information in terms of both EFF and uPER in their women's basketball team, the T-drill seems like their best option in order to achieve that.

Limitations and Recommendations for Future Studies

In general, our key intention is to promote the value of computer technology in supporting the development of SCCs' practice but also to stimulate more sports analytics research particularly for this key stakeholder in the modern world of sports. We acknowledge that our sample size was small, which resulted in being underpowered for the tests of significance. We reported the estimate of effect size (i.e., correlation), because the tests of significance were not adequately powered. In order to detect a correlation of .36 with 95% confidence and 80% power, the minimal sample size is 31. Future, larger-scale studies should replicate these finding across populations (e.g., professional athletes), settings (e.g., other DI programs, professional athletes in other countries, others fitness tests/MPIs), and times (e.g., administration of the same fitness tests in pre-season and/or in-season, if possible) in order to extend the limited external validity of our findings due to our use of convenience sampling. Lastly, future research should try to investigate the causality/mechanism behind the associations indicated by our results. Another potential limitation is the cross-sectional design of the off-season fitness tests.

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Appendix A

Warm-up (for 15 yards)

- Walking forward rotating arms forwards
- Walking backwards rotating arms backwards
- Walk forward, while pulling knees into chest with both hands
- Walk forward, while grabbing ankle behind the back with opposite hand
- High knees
- Butt kicks
- Defensive slides
- Carioca
- Sprint forwards
- Back pedal
- Walk forwards while kicking high in the air
- Exaggerated lunges while rotating body outside of leg
- Inch worms (Get into pushup position and then walk hands in, so that you form an upside-down U. Then, walk hands out into pushup position.)