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Workload Management Strategies to Optimize Athlete Performance in Collegiate Men's and Women's Basketball

Jacob Hurwitz[1,2], Darby Rich[3], Connor Agnew[4,5], John R. Harry[1]

[1] Human Performance & Biomechanics Laboratory, Texas Tech University, Lubbock, TX USA, [2] School of Kinesiology, Applied Health, and Recreation, Oklahoma State University, Stillwater, OK, USA, [3] Men's Basketball, Department of Athletics, Texas Tech University, Lubbock, TX USA, [4] Women's Basketball, Department of Athletics, Texas Tech University, Lubbock, TX USA, [5] Men's Basketball, Department of Athletics, Appalachian State University, Boone, NC, USA

ABSTRACT

Monitoring workload provides information about the physical demands in which athletes are competing in the sport of basketball. Sports scientists, strength and conditioning coaches and athletic trainers utilize this information to periodize and make decisions on practices and training program to optimize performance and prevent injuries. The purpose of the article was to describe our workload management process relative to collegiate men's and women's basketball players. We overviewed our process using inertial measurement units (IMUs) and ratings of perceived exertion (RPE) during individual and team training practices, competition, and return to play testing sessions to obtain external and internal workload information. We showed that workloads vary tremendously across both men's and women's athletes during each practice, game, and training sessions. In addition, we showed that workloads associated with organized practice are well-below competition workloads, and individual workload data should be summed with organized practice data to best understand the demands placed on basketball athletes. The processes outlined here can be followed or modified as appropriate to ensure that targeted demands are placed on athletes to maximize their potential to accommodate the typical workloads associated with competition. This work may stimulate subsequent reports from other collegiate programs to advance workload management protocols and build a body of literature that moves the field forward.

Keywords: External Workload, Internal Workload, Load Management, Return to Play, Sports Science

INTRODUCTION

Workload management has become a focal point of high-performance sports organizations due to potential benefits to athletes' preparation for competition. Within our high-performance basketball training environments, we have begun exploring ways to meaningfully incorporate contemporary technologies that provide data from which actionable decisions can be made. Such decisions should be aimed to optimize physical stimuli delivered to athletes at different stages of rehabilitation, physical training, competition, or a combination thereof (1, 13) with athletes' long-term goals and development in mind (31). Recent advancements in the area of wearable technology have provided mediums through which athletes' workload can be monitored during competition, organized practices, and individual training. This has become a focal point at multiple levels of competitive sport, particularly collegiate and professional basketball (19, 21, 25-27). There are different types of tracking systems that are used within team sports, along with the compatibility of their derived metrics for specific team sports. Tracking systems provide the collection of athletes external load data. Practitioners and such as sports scientist can use derived metrics to describe, plan, monitor and evaluate training and competition characteristics (30)..

It was reported that ~1.5 million high school and collegiate athletes experience injuries annually in the United States (11, 28). Specific to basketball, injuries appear to occur at a rate of 4.3 per 1000 athlete-exposures for athletes competing in the NCAA (6). As such, it is not surprising that workload management practices in high-performance basketball training environments prioritize reducing athletes' risk of musculoskeletal overuse injuries. While the cause of musculoskeletal overuse injuries is multifactorial, poor workload management has been identified as a major contributor (9, 10, 12, 23) due to impairments to decision-making, coordination, and neuromuscular control (17, 28). In general, the risk of musculoskeletal overuse injury is thought to increase when athlete workloads exceeds their functional capacity (28), highlighting the need to understand the workload levels for which athletes should be able to accommodate. However, workload management should not focus only on reducing workload to therefore minimize musculoskeletal overuse injury risk. Workload management should also be used to maximize athletes' preparation for the physical demands of competition. This is because competition can have unique workloads in comparison to the training environment or specific training activities. As such, it is critical to understand the demands an athlete must be able to effectively accommodate, which can be considered during training to reveal whether an athlete has sufficiently adapted in way that improves their ability to handle the demands of competition (22, 24).

A limiting factor related to the manner in which workload can or should be monitored in high-level basketball programs centers on the purposeful application of available technologies. This has been recently discussed related to professional men's basketball (27). However, professional athletes are a minority basketball playing population, and their training and workload management practices may not hold ecological validity for amateur players (e.g., college). The purpose of this report was to discuss our approach to assessing collegiate basketball athletes' workload as it relates to a) rehabilitation (i.e., return-to-play) and b) assessment of the applied stimulus delivered to our athletes throughout a competitive season. In particular, we will define workload and explain our approach to obtaining and managing the internal and external workloads we monitor to maximize applicability and replication where appropriate. As this article is specific to collegiate basketball athletes, all protocols and example data presented are specific to Division 1 men's or women's collegiate basketball athletes' workload during competition (i.e., games) and team and individual training sessions (i.e., practices, individual workouts, shoot-around, etc.). All athletes provided written informed consent prior to any collection of data, as approved by the Institutional Review Board at Texas Tech University (protocol number: IRB2018-802).

DEFINING WORKLOAD

Workload is defined as the combination of sport and non-sport stressors (28). Based on this definition, the collective workload athletes experience is the summation of the external and internal workloads (16). External workload is the external stimulus applied to the athlete (28). This means it represents the physical work done during training or competition, and is assessed using one of many objective measures, such as power output, time-motion and global positioning system (GPS) analysis of kinematic metrics (distance, speed, acceleration, etc.), and impact load (4).

Internal workload represents the physiological and psychological work done in response to the external load, and is influenced by genetic factors combined with daily life stressors, environmental considerations, and biological factors (28). Thus, internal workload can be thought of as the way in which an athlete reacts to biological stressors (4, 8). Common internal workload metrics include heart rate, blood lactate, oxygen consumption, and rating of perceived exertion, referred to as RPE (4). Importantly, commercial technologies can provide empirical information that can be used to monitor internal workloads, external workloads, or both, in addition to other contributing factors (e.g., recovery, sleep, hydration, etc.). However, the technologies available for internal and external workload management should be considered prior to application according the answered sought out by the practitioners, athletes, or both. This means the approach we use might not be ideal for all athlete populations, or even all collegiate basketball athletes, and this report should only be used to guide specific practices for each high-performance basketball environment.

OBTAINING EXTERNAL AND INTERNAL WORKLOAD DATA

We utilized inertial measurement units to obtain external workload information using the IMeasureU Step inertial units (Blue Trident sensors, Vicon Motion Systems, Ltd., Denver, CO, USA). This system is supported by mobile, desktop, and cloud-based analysis and interpretation applications, which we bridge with custom, in-house data management programs. The sensors were adhered bilaterally above the medial malleolus and record tri-axial tibial acceleration data representing the loading experienced by the lower limbs. The external workload metrics obtained from the sensor technology (15) are described in Table 1. We elected to utilize these sensors over other external workload technologies for multiple reasons. First, data obtained from the sensors have excellent inter-unit reliability for running-based team sport tasks (2). Second, common external workload technologies, such as GPS, are unreliable or not applicable to indoor environments (20). Third, it was critical for us to obtain external loads nearest the point of contact with the ground because that location is closest to where most injuries tend to occur (7). Fourth, by placing individual sensors on each limb, we are able to determine whether the external load placed on an athlete is experienced symmetrically, which has implications for our rehabilitation protocol (described later). The processed data is stratified by gravitational force intensity (i.e., low [1-5g], medium [6-20g], and high [21+g]).

We use session RPE to assess the internal workload experienced by our athletes. it has been shown to be a validated and accurate way of gathering subjective internal data from athletes (18). Session RPE data provides the athletes' subjective response of their exertion following on-court team practices, games, and individual on-court workouts. To obtain RPE information, we use a visual-analog scale will that is presented to the athletes at the end of

Table 1. External workload metrics provided by IMeasureU Step Sensors.

Impact Load	% Session Impact Load	Step Count	Bone Stimulus	Impact Asymmetry
The sum of each intensity created from every impact propagated into the lower limbs. Is comparable within and between sessions, allowing you to examine the loading outcomes of specific activities, sessions, and training days - and their respective effects on an athlete's workload Impact Load can be seen as high, medium, low intensity individually as a whole or combined.	The percentage of the Impact Load from the session. The percent session of impact load can be seen as high, medium, low intensity individually, as a whole or combined	This metric is how many steps an athlete takes on each limb based off of how hard the athlete step or land on each limb of high, medium, and or low intensity	An estimate of the mechanical stimulus that would cause the bone to respond and remodel. It is meant to give an approximation of how much load the tibia will adapt to during a given session. It should not be used as a general workload score nor does it approximate ground reaction forces. It is best employed to track recovery and stress in an athlete recovering from a bone injury	Describes the between-limb difference in mean average impact intensity. The Impact Asymmetry can be seen as high, medium, low intensity individually, as a whole or combined

a session (Figure 1). Our RPE scale uses slightly modified limits to align with the IMeasureU Step sensor intensity ranges, which includes three main classifications of workload. Therefore, 0-5 reflects low exertion, 6-10 reflects moderate exertion, and 11-15 reflects high exertion. This allows us to cross-reference our internal and external workload data as we see fit based on the patterns for either or both types of workload data.

PRACTICAL APPLICATIONS: WORKLOAD MANAGEMENT PROTOCOLS

Relative to rehabilitation, our primary objectives are to ensure athletes are a) no longer demonstrating the asymmetrical loading patterns they had prior to experiencing a musculoskeletal overuse injury (if necessary), and b) able to handle the typical external workloads of competition without overly high internal workloads. Relative to regular training and preparation, our primary objective is to ensure the athletes are prescribed appropriate internal and external workloads typical for a competitive game. In this section, we summarize the ways in which we seek to achieve these objectives, providing exemplar data where appropriate for context.

REHABILITATION (RETURN-TO-PLAY) PROTOCOLS

In order to for an athlete to return to play, having a clear understanding of the practical needs of the athlete when they return is crucial, along with a process that can be supported by practitioners and their ability to monitor and direct extrinsic and intrinsic workload progressions (29). For our rehabilitation protocol, athletes completed a physical test battery designed to provide a relatively symmetrical external stimulus (i.e., similar lower limb loading between limbs). During the athletes' initial weeks in the program or at the start of the annual training period, this test battery is performed three times to obtain baseline data related to the athletes' external workload symmetry. As described in Table 2, a battery of six tests are performed by the athletes (5-10-5 sprint, curved running, run-shuffle-run test, leap matrix, Gauntlet test, and the light reactive test). We collaboratively designed this test battery to match the training stimulus provided and our observations of the on-court skills needed by our athletes. As such, the ideal movements in the minds of other sports science or performance practitioners may differ from the ones described herein. Nonetheless, the external workload data from the test battery is used as baseline data to which subsequent data is compared if an athlete experiences an injury to determine their response to rehabilitation and preparedness to return to competition. The test battery typically takes ~45 minutes, with individuals or multiple athletes completing testing at the same time. Trials for each test were designed to last ~1 minute due to the 30-second binning of the data during processing (i.e., to isolate each test).

Session RPE	
0	Rest
1	Low Intensity
2	Low Intensity
3	Low Intensity
4	Low Intensity
5	Low Intensity
6	Medium Intensity
7	Medium Intensity
8	Medium Intensity
9	Medium Intensity
10	Medium Intensity
11	High Intensity
12	High Intensity
13	High Intensity
14	High Intensity
15	Maximal

Figure 1. Rating of perceived exertion scale used to assess internal workload

Table 2. Description of the rehabilitation test battery to assess athletes' readiness to return to competition.

5-10-5	Gauntlet	Run-Step-Shuffle	Leap Matrix	Reactive	Curved Running
Three cones are positioned in a line and separated by ~5 meters. The athlete begins at a center cone. To start the drill, the athlete sprints towards one of the cones, performs a change of direction and sprints to the farthest far cone. To finish, the athlete performs another change of direction to sprint back and through the starting location This is repeated for 3 repetitions, which combine to make 1 set. Athletes perform 2 total sets to each direction, with 30 seconds rest between sets.	Eight cones are set up in a rectangular position. To start, the athlete begins at the middle cone and shuffle left to another cone. The athlete then shuffles back to the original starting point. The athlete then sprints left at a ~45-degree angle to the side cone. The athlete will then shuffle back to the original starting cone. The athlete will then change direction and sprint to far cone and change in direction and run back to starting position cone. This sequence is immediately repeat going to the right. After completing the test in both directions, the athlete rests for ~2-minutes and repeats for one more set.	The athlete begins at the corner of the basketball court on the baseline facing the opposite end of the court. The test begins with the athlete sprinting along the baseline to the edge of center key and then shuffling across to the other edge of the key (~3.6 m). The movement concludes with the athlete sprinting to the corner of the baseline opposite the starting location. The athlete immediately performs the same movement in the opposite direction. Upon completion, the athlete rests for ~15 seconds and repeats for a second repetition. This will equal one set of two total sets.	Individual cones are positioned a) directly in front of the athlete, b) laterally to the left, c) laterally to the right, d) posterior to the left at a ~45°, and e) posterior to the right at ~45°. The athlete will perform three leaps to each cone with a 1-second pause between leaps to regain or maintain balance. A set is completed after leaping to each cone. Once the athlete completes the first set, they rest for ~30 seconds and then repeat for a second set.	Cones are positioned in front of and at ~45° to each side at ~3 meters from the starting cone. This test duration is for 30 seconds per set. The athlete will sprint or shuffle to a specific cone (randomly selected by a coach or practitioner) and back to the starting point. ~1-minute of rest is provided prior to performing the second and final set. This protocol was designed to replicate that of the Fitlight system (FITLIGHT, Miami, FL USA), which was originally used and programmed for a random sequence for the 30 seconds.	Athletes begin at one corner of the court where the baseline and 3-point line meet. The athlete begins by sprinting along the 3-point line to the opposite side, where they pivot, change directions, and sprint back to the starting position. Upon completion, the athlete will rest for ~15 seconds during which they walk to opposite side of baseline where they will perform another set of curved running. Four total times around the 3-point line equal one set. The athletes perform two total sets with ~2-minutes rest between sets

It should rarely be expected that an athlete's data will be identical to the data obtained at baseline or prior to an injury. As such, the objective of our rehabilitation is to determine whether the magnitudes of lower-limb loading reveal potential signs that the athlete is not yet prepared to handle the limb-specific or total body demands of the sport despite being medically cleared. Potential signs of inadequate preparation for training, competition, or both include excessively low or excessively high levels of lower-limb loading or RPEs, asymmetrical loading between the left and right limbs, and reduced performance of the test battery (e.g., times to complete the movements) when compared to the average across the baseline tests. While multiple analytical approaches exist for this purpose, we seek to reveal whether a difference or change between sessions exceeds the noise (i.e., coefficient of variation or "CV") observed during baseline testing, meaning we are not concerned with statistical probability testing. This is because the rehabilitation protocol involves individual athletes, thereby requiring a single-subject analysis approach (14). Any differences between baseline and follow-up tests indicate the athlete may need to continue rehabilitation or ease their way back into on-court practice and competition as prescribed by the coaching staff and performance and medical practitioners.

In our program, our primary focus is external loading (i.e., impact loading) asymmetry. Specifically, we compare the percent change of cumulative workload asymmetry between the post-rehabilitation test and the average from the baseline tests sessions to the variation observed across baseline tests (14). For context, we will consider one athlete's data. This athlete's average external loading asymmetry observed during three baseline tests was 19.4 ± 4.9% and the external loading asymmetry post-rehabilitation was 22.8%. Based on these data, there was a 17.5% increase of loading asymmetry. The corresponding CV threshold for this athlete (from the baseline data), which effectively represents the smallest acceptable increase of external loading asymmetry, was 25.3%. Accordingly, we concluded that the athlete was "ready" to return to play because the post-rehabilitation magnitude of loading asymmetry did not exceed the "noise" from the baseline tests. Obviously, this example only explains the process relative to external workload for one athlete, though our process is identically applied to the internal workload metric as well as other appropriate external loading metrics described in Table 1 for all athletes.

ON-COURT TRAINING PREPERATION PROTOCOLS

When we compare training loads to game loads, we first determine the typical workload experienced by athletes during games. For an example of this process, a subset of external workload data from 6 and 5 collegiate women's and men's basketball athletes, respectively, are provided (Table 3). From the game data, we calculate the average external workload experienced by athletes in addition to the 95% confidence interval (CI) to determine an estimate for the typical external workload athletes experience during competition. The same is done for internal workload (i.e., RPE) measures, and these values are updated monthly. In general, workloads are considered "over-stimulating" if they exceed the upper bound of the 95% CI obtained from the historical game data. Importantly, it is not concerning to us when the cumulative workload of a single day or week exceeds that which is experienced during a game. This is because the goal for our workload management process to ensure that the athletes are being stimulated sufficiently for the demands of competition.

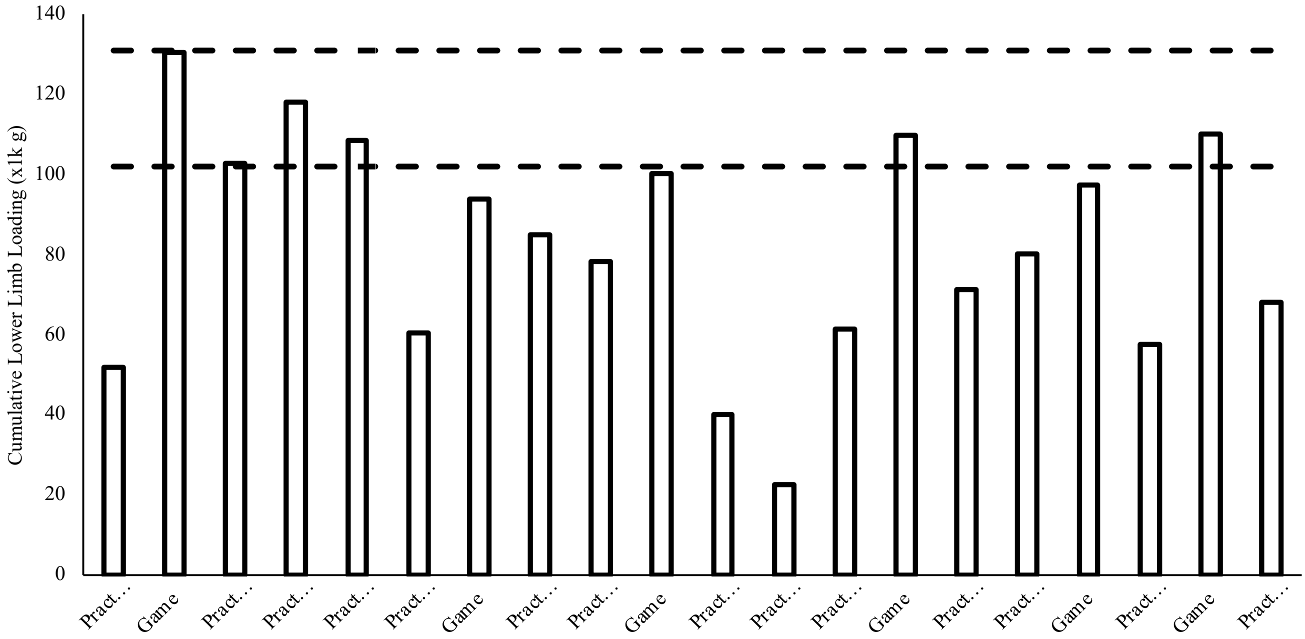
Our athletes usually complete daily on-court team practices and individual on-court sessions, with each providing relatively high external workloads. To contextualize the importance of obtaining workload data during each of these activities, data from one men's basketball athlete is provided only for on-court team practices and games (Figure 2). As shown in the figure, excluding the individual on-court work-outs can alarmingly suggest an athlete is under-loaded in terms of preparation for the external workloads experienced during a typical game (average across practices: 82.5k g; typical game: 108k g to 129k g). Accordingly, we monitor daily workloads as the sum of all on-court sessions during a given day. Those workloads are then compared to historical game workloads collected over previous and current seasons (i.e., the game load database continually grows). Ideally, we seek to have the average workload athletes experience over a specific time period (weekly, monthly, etc.) "match" the workload typically experienced during a game. This means that on some days, athletes will experience greater or lesser workloads than they experience during a game, which is expected, similar to volume fluctuations that are prescribed during resistance training protocols (3). The specific workload fluctuations or consistencies we deem acceptable are determined on a case-by-case or team-by-team (i.e., year by year) basis.

Table 3. Historical External Workload Data during Collegiate Women's and Men's Basketball Games.

	Women's Team							Men's Team				
Game	Athlete 1	Athlete 2	Athlete 3	Athlete 4	Athlete 5	Athlete 6	Game	Athlete 1	Athlete 2	Athlete 3	Athlete 4	Athlete 5
1	158.4	97.9	130.6	88.3	73.1	72.9	1	120.6	74.4	105.3	116.1	152.7
2	180.1	94.6	145.4	96.6	89.2	122.9	2	135.1	261.3	91.1	185.8	111.8
3	155.5	104.6	126.9	126.5	78.6	112.2	3	134.9	82.3	86.4	131.5	149.9
4	153.0	87.5	140.9	124.7	113.9	73.2	4	110.1	149.6	84.2	116.5	98.6
5	137.1	109.9	112.9	22.2	78.6	89.0	5	97.3	155.7	79.6	x	88.1
6	130.7	96.4	152.6	132.4	103.8	x	6	109.8	130.4	83.8	x	x
7	167.2	87.5	146.4	x	98.5	x	7	100.3	139.5	154.9	x	x
8	158.9	90.0	129.5	x	93.1	x	8	94.0	120.8	76.9	x	x
9	x	79.4	143.5	x	x	x	9	130.5	115.4	102.0	x	x
10	x	101.0	152.7	x	x	x	10	102.8	120.5	61.0	x	x
11	x	100.1	142.5	x	x	x	11	106.9	x	143.1	x	x
12	x	24.7	133.0	x	x	x	12	138.5	x	91.3	x	x
13	x	103.9	176.1	x	x	x	13	144.2	x	x	x	x
14	x	x	163.2	x	x	x	14	146.6	x	x	x	x
15	x	x	137.4	x	x	x	15	x	x	x	x	x
Mean	155.1	90.6	142.2	98.5	91.1	94.0	Mean	119.4	135.0	96.6	137.5	120.2
SD	15.7	21.5	15.4	41.3	14.0	22.7	SD	18.5	51.5	27.1	33.0	29.6
Target Workload	115.3 ± 34.1 [106.1 – 124.5]						Target Workload	118.5 ± 34.7 [108.1 - 128.9]				

Notes – unit of measure of external workload: units of gravitational acceleration, in thousands (i.e., 83.4 = 83,400 g); Target workload data are presented as Mean ± SD [95% Confidence Interval].

Figure 2. Real external workload data from one men's team player during 14 practices and six games



Notes – dashed lines represent the 95% CI band related to the typical workload of a game, calculated across athletes and current and previous seasons.

Because we emphasize a longer-term approach to workload management, the pattern of cumulative workloads for each athlete is monitored to determine whether the targeted trajectory for the external stimulus is met. For example, at the start of a preparatory season, such as the first few weeks of organized training, the coaches might intend to incrementally ramp up cumulative (practice + individual session) intensities from moderate to high (or similar). The external workload data is used to determine whether than planned trajectory actually occurs by matching the coaches planned intensity for each day's activities to the athletes' workload (low: below the target workload range; high: above the target workload range), and we assess the difference/change in workload from week to week using aforementioned CV approach. For example, if one athlete's week 1 and week 2 cumulative external loading was 82.2k g ± 17.9k g and 148.3k g ± 34.1k g, the CV-based threshold for an increase of workload would be 21.8%. As the percent change in workload from week 1 to week 2 is 80.4%, there was an important increase from week 1 to week 2 but the magnitude of external loading also exceeded the target loading of a game. From that data, the following week's training objectives can be prescribed or modified to best stimulate and prepare the athletes, both individually and as a group.

Once training nears the start of a competitive season and beyond, we closely monitor whether an athlete is over-stimulated over consecutive weeks with respect to external and internal workloads. If observed, we do not recommend, in most cases, removing the athlete from practice(s) or competition(s). This is because lower external workloads have been linked to higher injury risk in basketball (5). Instead, we consider an in-house hierarchy relative to each athlete preparation within which activities are ranked during specific training or seasonal periods. For instance, during the season, our priority of activities for an athlete is often categorized in the following order (highest to lowest): competition (i.e., games), team practice, strength & conditioning, individual workouts/shoot-around. Accordingly, for an athlete who is consistently over-loaded for a specific period of time, we might temporarily reduce the number of, or eliminate, individual workouts as the first logical step. This is to continue appropriately preparing the athlete for competitive workloads without compromising the individual athlete's, or the team's, potential for positive adaptation or success during competition. Conversely, for athletes consistently under-loaded, we might consider their situational demands during practice or the specific activities performed within strength & conditioning or individual workouts to appropriately increase their workload.

Table 4 provides a visual representation of daily and average lower limb external loading from three women's basketball athletes across seven on-court practices (i.e., excluding individual sessions on the same day). These athletes were selected for this example to demonstrate the variation of external loading across athletes and how those variations can be used to modify training as appropriate. As shown in the table, across, one of those athletes (Athlete 1 in the table) demonstrated external workloads that were more than three-fold greater than two other athletes and also greater than the workloads of a typical game. Once we detected the anomalous pattern of loading in this athletes, we were able to focus on the specific aspects of their on- and off-court work. Upon focus observation, we found that this athlete was volunteering for drill demonstrations and seeking extra repetitions of high-impact drills during practices. This provided us with an opportunity to control such repetitions during practice where appropriate, restrict individual on-court session, or both, to reduce the athlete's potential of a workload-related injury. Ultimately, this athlete did experience a minor overuse lower-limb injury (tarsal bone bruise) shortly after this set of practices, but we are confident that our data-driven modifications to their workload prevented a more serious overuse injury such as a stress fracture.

In summary, collegiate basketball athletes experience cumulative workloads that can monitored using both external and internal approaches. In our program, we employ two protocols. The first protocol is to ensure that rehabilitated athletes are able to both demonstrate bilateral loading patterns that similar to their baseline tests and able to handle the typical external workloads. Relative to regular training and preparation, our protocol is to ensure the athletes are prescribed appropriate internal and external workloads to prepare them for the typical workloads experience in a competitive game. This report is not meant to serve as a "cookie-cutter" protocol to be replicated in other collegiate basketball programs. Instead, it is provided as a means to stimulate subsequent reports from other collegiate programs to advance workload management protocols and build a body of literature that moves the field forward.

Table 4. External Workloads during Practice for Three Collegiate Women's Basketball Athletes.

Practice Session	Athlete 1	Athlete 2	Athlete 3
1	98.2	33.8	28.1
2	101.0	46.3	57.5
3	124.7	38.3	45.6
4	218.6	48.3	49.8
5	121.4	40.2	33.2
6	133.2		47.5
7	111.1		26.8
Average ± SD	129.7 ± 41.2	41.4 ± 5.9	41.2 ± 11.8

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CONFLICT OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

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REFERENCES

1. Alaina Locus, Jay Williams, Angela Anderson, and Speicher L. Designing a Return to Activity Protocol for a Proximal Hamstring Rupture in a Collegiate Heptathlete: A Case Study. 2021.
2. Armitage M, Beato M, and McErlain-Naylor SA. Inter-unit reliability of IMU Step metrics using IMeasureU Blue Trident inertial measurement units for running-based team sport tasks. J Sports Sci 39: 1512-1518, 2021.
3. Bompa TO, & Carrera, M. . Periodization training for sports. Champaign, IL: Human Kinetics, 2005.
4. Bourdon P, Cardinale M, Murray A, Gastin P, Kellmann M, Varley M, Gabbett T, Coutts A, Burgess D, Gregson W, and Cable N. Monitoring Athlete Training Loads: Consensus Statement. International Journal of Sports Physiology and Performance 12: 161, 2017.
5. Caparrós T, Casals M, Solana Á, and Peña J. Low External Workloads Are Related to Higher Injury Risk in Professional Male Basketball Games. J Sports Sci Med 17: 289-297, 2018.
6. Dick R, Hertel J, Agel J, Grossman J, and Marshall SW. Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. J Athl Train 42: 194-201, 2007.
7. Edwards S, White S, Humphreys S, Robergs R, and O'Dwyer N. Caution using data from triaxial accelerometers housed in player tracking units during running. J Sports Sci 37: 810-818, 2019.
8. https://www.firstbeat.com/en/blog/why-monitor-internal-load-in-elite-sports/.
9. Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc 30: 1164-1168, 1998.
10. Foster C, Daines E, Hector L, Snyder AC, and Welsh R. Athletic performance in relation to training load. Wis Med J 95: 370-374, 1996.
11. Fraser-Thomas J, Côté J, and Deakin J. Examining Adolescent Sport Dropout and Prolonged Engagement from a Developmental Perspective. Journal of Applied Sport Psychology - J APPL SPORT PSYCHOL 20: 318-333, 2008.
12. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? Br J Sports Med 50: 273-280, 2016.
13. Glassbrook DJ, Fuller JT, Alderson JA, and Doyle TLA. Measurement of lower-limb asymmetry in professional rugby league: a technical note describing the use of inertial measurement units. PeerJ 8: e9366, 2020.
14. Harry R, John, Hurwitz, W., Jacob, Rich, Darby, Agnew, Connor, Bishop, Chris. Assessing True Change in Individual Athletes. Journal of Strength and Conditioning Research, 2022.
15. https://imeasureu.com/imu-step/.
16. Impellizzeri. Monitoring training load in Italian football. Paper presented at: 8th Annual Congress of the European College of Sport Science, 2003.
17. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, and Marcora SM. Use of RPE-based training load in soccer. Med Sci Sports Exerc 36: 1042-1047, 2004.
18. Losnegard T, Skarli S, Hansen J, Roterud S, Svendsen IS, B RR, and Paulsen G. Is Rating of Perceived Exertion a Valuable Tool for Monitoring Exercise Intensity During Steady-State Conditions in Elite Endurance Athletes? Int J Sports Physiol Perform: 1-7, 2021.
19. McLean BD, Strack D, Russell J, and Coutts AJ. Quantifying Physical Demands in the National Basketball Association-Challenges Around Developing Best-Practice Models for Athlete Care and Performance. Int J Sports Physiol Perform 14: 414-420, 2019.
20. Motte H, Wyffels J, De Strycker L, and Goemaere J. Evaluating GPS Data in Indoor Environments. Advances in

Electrical and Computer Engineering 11: 25-28, 2011.
21. Paulauskas H, Kreivyte R, Scanlan AT, Moreira A, Siupsinskas L, and Conte D. Monitoring Workload in Elite Female Basketball Players During the In-Season Phase: Weekly Fluctuations and Effect of Playing Time. Int J Sports Physiol Perform 14: 941-948, 2019.
22. Piedra A, Peña J, and Caparros T. Monitoring Training Loads in Basketball: A Narrative Review and Practical Guide for Coaches and Practitioners. Strength and Conditioning 43: 12-35, 2021.
23. Piggott B NM, McGuigan MR. . The relationship between training load and incidence of injury and illness over a pre- season at an Australian Football League club. J Aust Strength Cond, , 2009.
24. Pino-Ortega J, Rojas-Valverde, D., Gómez-Carmona, C. D., Bastida-Castillo, A., Hernández-Belmonte, A., García-Rubio, J., ... & Ibáñez, S. J. . Impact of contextual factors on external load during a congested-fixture tournament in elite U'18 basketball players. Frontiers in Psychology, 2019.
25. https://leadersinsport.com/performance/kinexon-athlete-monitoring-in-the-nba/.
26. Russell JL, McLean BD, Impellizzeri FM, Strack DS, and Coutts AJ. Measuring Physical Demands in Basketball: An Explorative Systematic Review of Practices. Sports Med 51: 81-112, 2021.
27. Russell JL, McLean BD, Stolp S, Strack D, and Coutts AJ. Quantifying Training and Game Demands of a National Basketball Association Season. Frontiers in Psychology 12, 2021.
28. Soligard T, Schwellnus M, Alonso JM, Bahr R, Clarsen B, Dijkstra HP, Gabbett T, Gleeson M, Hägglund M, Hutchinson MR, Janse van Rensburg C, Khan KM, Meeusen R, Orchard JW, Pluim BM, Raftery M, Budgett R, and Engebretsen L. How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. Br J Sports Med 50: 1030-1041, 2016.
29. French D, and Ronda LT. NSCA's Essentials of Sport Science. Human Kinetics, 2021.
30. Torres-Ronda L, Beanland E, Whitehead S, Sweeting A, and Clubb J. Tracking Systems in Team Sports: A Narrative Review of Applications of the Data and Sport Specific Analysis. Sports Med Open 8: 15, 2022.
31. West SW, Clubb J, Torres-Ronda L, Howells D, Leng E, Vescovi JD, Carmody S, Posthumus M, Dalen-Lorentsen T, and Windt J. More than a Metric: How Training Load is Used in Elite Sport for Athlete Management. Int J Sports Med 42: 300-306, 2021.