



## Value of Wellness Ratings and Countermovement Jumping Velocity to Monitor Performance

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### ABSTRACT

*International Journal of Exercise Science* 12(4): 88-99, 2019. This study examined the relationship between subjective ratings of overall wellness and neuromuscular performance throughout a 6-week intensive offseason strength and conditioning program. Thirty experienced NCAA Division II baseball players completed all phases of the program. A comprehensive wellness rating and 5 countermovement jumps (CMJ5) were measured and averaged for 4 phases of training. Pre- and post-testing measures of strength and speed also were evaluated. Internal consistency of the wellness rating for each phase ranged  $\alpha = 0.77-0.92$ , and CMJ5 velocities had decent consistency ( $ICC_{\alpha} = 0.88$ ,  $TE = 0.19 \text{ m}\cdot\text{s}^{-1}$ ,  $CV = 5.90\%$ ). The training program evoked significant ( $p < 0.01$ ) improvements in front squats ( $d = 0.55$ ), trap bar deadlifts ( $d = 0.62$ ), chin ups ( $d = 0.39$ ), 30-yd dash ( $d = 0.39$ ), with no change in the 300-yd dash ( $p > 0.05$ ), where  $d$  is the treatment effect size. Average CMJ5 velocities ( $\text{m}\cdot\text{s}^{-1}$ ) were similar for the preparation phase ( $1.90 \pm 0.25$ ), eccentric phase ( $1.91 \pm 0.28$ ), strength & power phase ( $1.91 \pm 0.24$ ), and recovery phase ( $1.91 \pm 0.30$ ;  $F = 0.04$ ,  $p = 0.99$ ,  $\eta_p^2 = 0.001$ ). No significant correlations were observed for pre- or post-testing measures of wellness ratings in comparison to any performance measures, including a composite standardized score from each performance test at pre-testing ( $r = 0.22$ ,  $p = 0.26$ ). The CMJ5 exhibited too high of a typical error to determine a change in neuromuscular status. Additionally, the wellness rating did not reflect changes in relation to performance.

**KEY WORDS:** Baseball, linear position transducer, neuromuscular fatigue, performance monitoring, wellness questionnaire

### INTRODUCTION

Overtraining syndrome (OTS) and nonfunctional overreaching (NFOR) are defined as severe prolonged maladaptations of athletic performance whereby an imbalance between training load and recovery evokes varying physiological, neurochemical, and hormonal decrements (10, 17). Distinguishing OTS from NFOR is difficult, and there is limited evidence that NFOR precedes OTS (17). Conversely, short-term performance decrements without long-term negative

symptoms is referred to as functional overreaching (FOR) (17). Throughout the training calendar, the goal of periodization is to strategically implement short periods of intensified training to induce FOR followed by a period lower intensity for evoking a “supercompensation effect” to enable maximal performance (28). Ideally, strength & conditioning (S&C) professionals strive to prescribe training to induce FOR followed by adequate recovery for peaking.

No single criterion exists for diagnosing OTS; therefore, measuring one biological system during a training period may be misleading (25). Selye (22) suggested originally that a wide range of medical conditions or events can evoke stress, and that individuals respond to stress nonspecifically. Two individuals may be biologically stressed, but the source of that stress (good or bad) is variable. Similarly, no two athletes with OTS have identical signs and symptoms, making it difficult to identify problems (21, 23). Whether the stress comes from a period of intense training, competition, academics, or another meaningful life stressor, the cumulative biological consequences and risk of injuries increase substantially (9, 12, 15). In order to insure the training prescription is improving athletic performance and to be able to recognize athletes who may be failing to cope with these stressors, S&C professionals should take a multidimensional approach to athletic monitoring (20, 25).

The physiological underpinnings of central and peripheral fatigue are multifactorial and are not fully elucidated (3, 11). Common signs of fatigue include declines in maximal force production and power output, decreased velocity of muscle shortening, post contraction relaxation, loss of height and concentric velocity in vertical jumping, and various biochemical markers in the brain and muscle fibers (2, 7, 11, 16, 18, 20). Consequently, many S&C professionals utilize various jump evaluations with equipment such as linear position transducers (LPT), force plates, and contact mats for monitoring neuromuscular performance. With a variety of useful tests such as a squat jump, countermovement jump (CMJ), weighted jumps, and repeated jumps, we have access to more technology and data than ever before. As CMJs involve multi-joint actions of the lower extremities, that action remains popular as test motion for monitoring neuromuscular fatigue (7-9, 24, 26).

Psychological wellness is as equally important as the physiological load during periods of FOR, and both must be monitored to effectively gauge the cumulative load placed on the individual (4, 16). Thus, a simple and effective means for monitoring perceived fatigue and/or wellness during periods of high stress should be implemented for the safety of the athlete. Researchers have experimented with different questionnaires for gauging self-reported wellness and reported correlations between changes in perceived fatigue, stress, sleep quality, soreness, and mood with changes in CMJ height during a period of FOR (1, 9, 16, 24). Yet, some psychological questionnaires take a substantial amount of time to complete, which may lead to monotony, boredom, and poor response quality. Thus, research on shorter scales is warranted (5).

Despite the increased availability of monitoring strategies, research has yet to elucidate clear guidelines on effective strategies to implement jump and wellness monitoring within a team sport setting. Therefore, the purpose of this study was to examine the relationship between

subjective ratings of overall wellness and neuromuscular performance throughout a 6-week intensive offseason training program in a collegiate S&C setting. Our hypothesis was that overall ratings of wellness and mean concentric velocity of a CMJ would decline as the training program progressed, but rebound subsequent to a 5-day recovery period.

## **METHODS**

### *Participants*

A group NCAA Division II baseball players consented to participate in pre- and post-testing performance measurements consisting of front squats, deadlifts, chin ups, 30-yard sprint, 300-yard shuttle, and instantaneous velocity monitoring of CMJs surrounding a 6-week off-season training program. Due to the ease of monitoring jumps, those measures were collected throughout the duration of the training program. Self-reported wellness measures were collected at the beginning of each workout. Statistical analyses focused on identifying performance adaptations, and whether a measure of wellness is sensitive for detecting changes in performance.

Thirty Caucasian male collegiate baseball student-athletes ages  $20 \pm 1$  yrs completed all phases of this study. Participants had a mean height of  $185.5 \pm 5$  cm and mean weight of  $89.9 \pm 8.2$  kg. All participants had at least one year of resistance training experience prior to starting the program, underwent a sports physical by a licensed physician, and signed a form acknowledging their abstinence from using performance enhancing substances. All procedures were approved by our institutional review board, and all participants signed an informed consent document to participate in the study.

### *Protocol*

The training program consisted of four phases, each with a different training emphasis: preparatory, hypertrophy, strength & power, and recovery. The weekly layout of the program consisted of plyometric and total body, multi-joint, heavy resistance training sessions on Monday, Wednesday, and Friday. The main exercises utilized were trap bar and Romanian deadlifts, front and split squats, kneeling landmine presses, chin ups and pull downs, dumbbell and inverted rows, hamstring curls, and various trunk stability and posterior shoulder/rotator cuff exercises. The order of exercise selection for the hypertrophy and strength & power phase was influenced by programs recommended by Kenn (14). Following the warm up, each session began with a series of torso stability and explosive total body exercises, such as maximal effort medicine ball throws, and jumps. Next, the main exercise for the day (i.e. Deadlift, Front Squat, or a press variation) was performed at a prescribed load based on a percentage 1 repetition maximum (1RM), to the nearest 5 lbs, and paired with two explosive movements involving similar movement patterns to utilize the benefits of post-activation potentiation (27). A speed/agility session took place on Tuesdays, and a conditioning session on Thursdays. The dynamic warm ups, mobility/flexibility cool down routines, training times of day, and layout of each session remained constant throughout the program. All sessions were 45-60 minutes in duration.

The preparatory week consisted of baseline performance testing where participants were tested in the 30-yard sprint from a lead-off stance on Tuesday, 1-3RM Front Squat and Trap Bar Deadlift, and chin ups for maximum reps on Wednesday, and a 300-yard shuttle test on Thursday. Monday and Friday included teaching lifting technique and low intensity bodyweight, medicine ball, and dumbbell general strength circuits. The same protocol was followed during the last week of training to ascertain post-testing results. Circuits consisted of about 24 exercises ranging from 10-20 repetitions per set and less than 60-second rest periods with the goal of enhancing muscular endurance and aerobic qualities without accumulating excessive amounts of fatigue and/or soreness.

The 2-week eccentric phase was comprised of resistance exercises that involved a 4-second eccentric emphasis to increase time under tension and muscular damage, two important factors in stimulating hypertrophy (6). The main exercise for each day was prescribed at four sets of four repetitions at 65% 1RM load for the first week and 75% 1RM load for the next. Almost all assistance exercises emphasized the eccentric phase and involved three sets of 8-15 repetitions. Most exercises were performed to volitional fatigue.

The next phase was a 2-week strength & power phase. This phase involved eliminating the eccentric emphasis, minor advancements in some plyometric and assistance exercises [e.g. Eccentric dumbbell (DB) split squat progressed to DB walking lunges, and a pause drop jump progressed to reactive drop jump], and a slight increase in repetition volume for assistance exercises. The load was increased to 80% 1RM for four sets of five repetitions for the first week and 85% 1RM for four sets of four repetitions the following week.

Prior to each session, participants filled out a wellness questionnaire modeled after McLean et al (16). with five rankings, scaled 1-5, related to level of fatigue, sleep quality, general muscle soreness, stress, and mood. Composite scores ranged from 5-25 for each day with 25 being the most ideal state of wellness. Following the dynamic warm up and a 2-5-minute rest period, participants completed five consecutive countermovement jumps (CMJ5) measured using a linear position transducer (GymAware Power Tool, model #1759, Kinetic Performance Technology, Canberra, AU). The cord was Velcro-strapped to the subject's middle finger, and they were instructed to place their hands firmly on their hips to eliminate arm action from the jump. Data were instantaneously synchronized to the online cloud software. On Tuesday of the preparatory week, a tape measure was used to measure 30-yards and a timing system (Brower Timing TC-System, Draper, UT) was set at the start and finish lines to digitally record sprint times. Participants were given two attempts and the better of the two was recorded. On Thursday, participants performed the 300-yard shuttle tests, which consisted of completing five laps back and forth between two lines 60 yards apart. The tests were timed manually (Accusplit Pro Survivor 601x 3V.1 stopwatches) starting at the sound of the coach's whistle, and stopping as the subject passed the finish line. Participants were instructed to run as fast as possible and were given one attempt. On Wednesday, participants were evaluated to determine their 1-3 repetition maximum (RM) for the front squat and deadlift, and maximum repetitions for chin ups. Participants were educated on safety and the protocol of 1-3 RM testing prior to testing, then were instructed to complete 4-5 warm-up sets with increasing load until an estimated 1-3

RM load was reached. All attempted maximum sets were evaluated by the S&C staff, and the subsequent sets and loads were determined by the coach until a 1-3 RM was obtained (defined to the nearest 5 lbs). Next, chin ups were evaluated on a straight pull up bar with a supinated, shoulder width grip and repetitions were classified as the participants' elbows starting fully extended in a hanging position and finishing with the chin clearing the top of the bar. Participants could warm up as needed, and were given one attempt to reach maximum number of repetitions. Any repetition that involved swinging/kicking of the lower body was not counted. All sets were judged and recorded by the S&C staff.

### *Statistical Analysis*

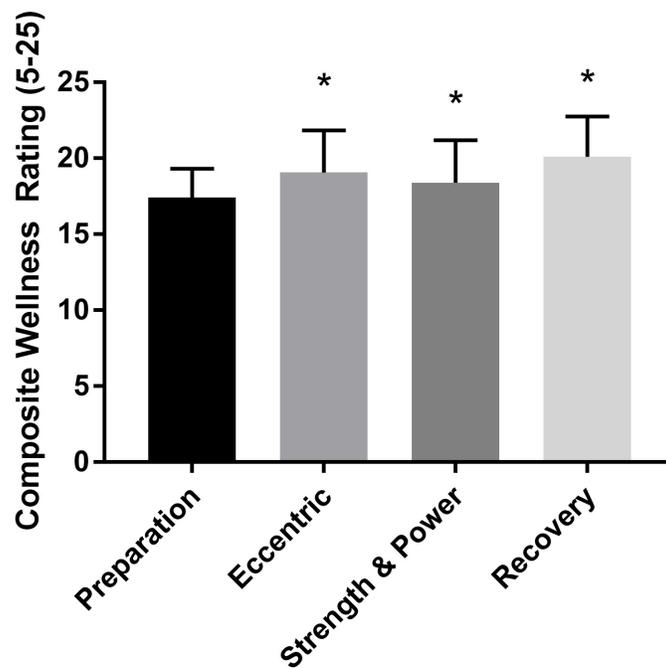
All data were screened for violation of normality, skewedness, and outliers. Internal consistency reliability with the five individual items of the wellness rating were evaluated using Cronbach's alpha ( $Cron_{\alpha}$ ), and an average composite score was used as a single measure of wellness for subsequent statistical analyses. To evaluate the variability of the average and peak concentric velocities of the CMJ5, we calculated internal consistency reliability using an intraclass correlation coefficient ( $ICC_{\alpha}$ ), typical error (TE), and coefficient of variation (CV)(13). Based on those analyses, we arrived at a decision to use average instead of peak velocity as the dependent variable for CMJ5 performance. To derive an overall performance score at pre- and post-training, standardized ( $z$ ) scores were calculated for each test, and averaged to yield a single composite performance score (19). Changes in pre-to post-training were calculated and the magnitude of the treatment effect was quantified using Cohen's  $d$ . The individual scores and  $z$  scores at pre- and post-testing were correlated with the composite wellness score using Pearson-product moment correlation coefficient ( $r$ ) statistic. The  $r$  value comparisons between average concentric velocities of the CMJ5 and composite wellness score also are reported for each phase of training. In an effort to quantify any ability of the wellness score to detect changes in performance from pre- to post-training, a correlation was performed between composite standard difference score for all tests pre-to-post training and changes in composite wellness ratings. Improvements in performances from pre-to post testing were evaluated using a series of paired t-tests. Separate analyses of variance with repeated measures using a LSD analysis for exploring main effects relative to the four phases of training were used to detect any differences in mean concentric velocity and wellness scores, respectively. Rejection of all null hypotheses was accepted at  $p < 0.05$ . All measures of central tendency and variability are reported as mean  $\pm$  SD; however, frequency distributions for the composite wellness scores are reported for each phase of training.

## **RESULTS**

Although the 5-item wellness score was assessed preceding each workout, the values were averaged across each training phase and internal consistency reliability coefficients were evaluated. Strong internal consistency reliability ( $Cron_{\alpha}$ ) values were observed for the preparatory phase (0.77), eccentric phase (0.92), strength & power phase (0.92), and the recovery phase (0.81). Slightly better internal consistency reliability (average of the four training periods) was observed for average ( $ICC_{\alpha} = 0.88$ ,  $TE = 0.19 \text{ m}\cdot\text{s}^{-1}$ ,  $CV = 5.90\%$ ) versus the peak ( $ICC_{\alpha} =$

0.91, TE = 0.12 m·s<sup>-1</sup>, CV = 6.50%) concentric velocities for the CMJ5. Therefore, average velocity was used for all subsequent statistical analyses.

Average concentric velocities (m·s<sup>-1</sup>) were remarkably similar for the preparation phase (1.90 ± 0.25), eccentric phase (1.91 ± 0.28), strength & power phase (1.91 ± 0.24), and recovery phase (1.91 ± 0.30) ( $F = 0.04$ ,  $p = 0.99$ ,  $\eta_p^2 = 0.001$ ). With exception of the 300-yard shuttle, the training program evoked significant improvements in measures of total body strength and speed (Table 1). Relative to the preparatory phase, higher wellness ratings were observed throughout the training program, with the strength & power phase having slightly, but significantly lower wellness ratings in comparison to the eccentric and recovery phases of the program (Figure 1).



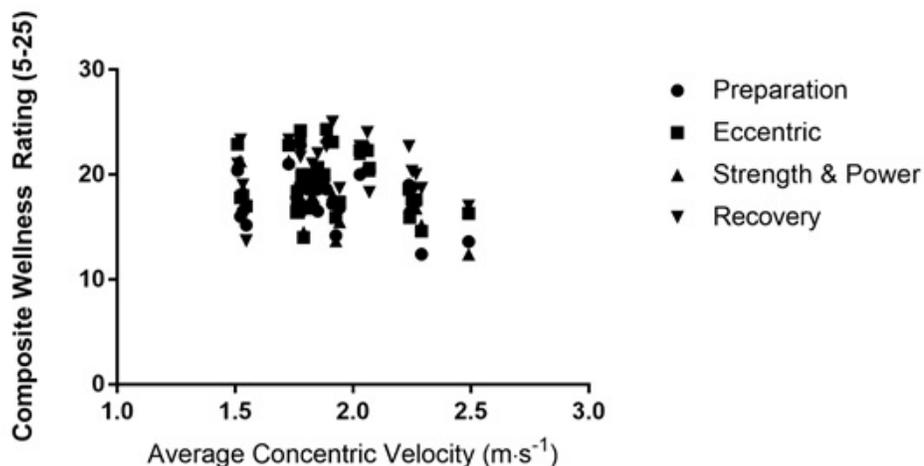
**Figure 1.** Composite wellness ratings (M ± SD) across each training phase (N = 30). \*Significantly ( $p < 0.05$ ) different from each preceding phase of training.

**Table 1.** Performance results (M ± SD) at pre and post testing (N = 30) where change scores are in the units of measurement and effect sizes (ES) are calculated using Cohen’s *d*.

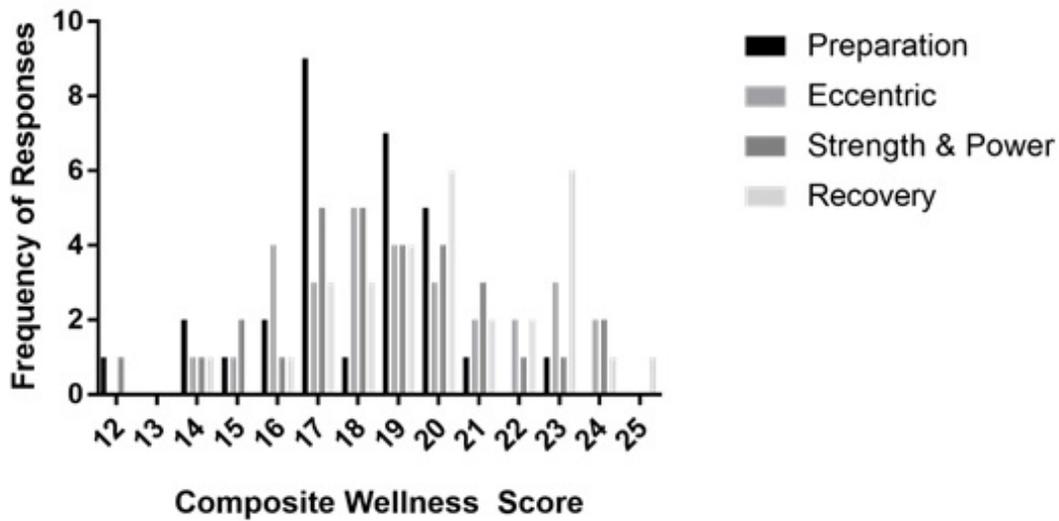
	Front Squat**	Trap Bar Deadlift**	Chin up (reps)	30 yd dash(s)	300 yd shuttle(s)	Countermovement Jump Velocity(m·s <sup>-1</sup> )
<b>Pre</b>	1.41 ± 0.23	2.10 ± 0.32	14 ± 6	3.92 ± 0.15	44.87 ± 1.89	1.90 ± 0.24
<b>Post</b>	1.55 ± 0.28	2.32 ± 0.32	17 ± 6	3.87 ± 0.14	45.05 ± 1.90	1.91 ± 0.29
<b>Change</b>	0.14 ± 0.05	0.22 ± 0.07	2 ± 0.17	0.06 ± 0.01	0.18 ± 0.01	0.003 ± 0.068
<b>ES (<i>d</i>)</b>	0.55	0.62	0.39	-0.39	0.10	0.01
<b>t statistic</b>	11.8	7.1	5.4	4.4	0.73	0.06
<b>p-value</b>	<0.01*	<0.01*	<0.01*	<0.01*	0.47	0.95

\*\* Relative to body mass  
\* Significant improvement

Despite having only 5-items, each with a 5-point Likert scale, the composite wellness ratings were normally distributed for each phase of training (Figure 2). No significant relationships were observed between the wellness ratings and average concentric velocities measures during any of the four phases of training (Figure 3). Moreover, no significant correlations were observed for pre- or post-testing measures of the wellness ratings with any of the performance measures, including a composite standardized (*z*) score from each performance test (Table 2). Finally, there was no significant correlation between a change in the wellness rating and composite standard difference score, which was based on the change in raw performance measures evaluated at pre- and post-training (*r* = -0.22, *p* = 0.26).



**Figure 2.** Scatterplots denoting no significant (*p* > 0.05) correlations between the composite wellness score and average concentric velocity for squat jump performances for each phase of training.



**Figure 3.** Histograms denoting normal distributions of composite wellness scores for each phase of training (Note: a small, non-significant, negative skew was observed in the recovery phase).

**Table 2.** Pearson product-moment correlation coefficients between the composite wellness ratings and six separate performance scores at pre and post testing (*N* = 30)

	Front Squat	Trap Bar Deadlift	Chin Ups	30-yd Dash	300-yd Shuttle	Countermovement Jump Velocity	Composite Z Score
<i>Pretest</i> Correlations with Wellness Ratings							
r value	0.07	0.11	0.02	-0.05	-0.10	-0.22	0.03
p value	0.71	0.57	0.91	0.78	0.61	0.25	0.87
<i>Posttest</i> Correlations with Wellness Ratings							
r value	0.05	0.01	0.05	0.16	-0.05	-0.09	0.02
p value	0.71	0.99	0.81	0.40	0.80	0.65	0.93

## DISCUSSION

The major findings of the present study are as followed. Data from the questionnaires indicated a moderate to high internal consistency reliability, implying that all five questions (i.e., fatigue, sleep quality, muscle soreness, stress level, and mood) consistently represented the overall wellness rating. Additionally, overall wellness from beginning to end of the program improved in conjunction with pre and post-performance measures related to strength and speed, but not 300-yard shuttle; however, the wellness rating correlated poorly with performance (Figure 2). Measuring concentric velocity during a countermovement jump was an unsuitable metric for monitoring change in performance due to its large variability. Such an aspect will be expounded upon.

The composite wellness course did not correlate with any of the performance measures (Table 2). As the principal focus of the present study was to evaluate the CMJ as a screening metric, we opted to use the average as opposed to peak linear velocity measure because of the slightly better test-retest reliability. We should note that too much homogeneity within scores of a given variable would decrease the likelihood of detecting a significant correlation; however, despite a wide range of wellness scores, there was no relationship between composite wellness rating and CMJ5 performance (Figure 2). Although the CMJ5 performance across phases was conceivably too homogeneous, a plausible alternative interpretation is that these two metrics assess different components of FOR due to the poor correlation between these two metrics.

While our findings may raise questions about the utility of the wellness questionnaire and the jump velocity protocol, it is possible that the failure of these metrics to detect changes in FOR are simply indicating that the imposed program did not sufficiently stress the athletes to reach FOR. The program was effective at delivering performance improvements within the selected tests (Table 1); yet, these data may indicate that the athletes were capable of tolerating and adapting to higher exercise intensities or volumes. For example, increased soreness is a hallmark response to eccentric contractions (6) and we would expect athletes training in a phase with an eccentric emphasis to experience more soreness and potentially lower vertical jumping velocities as a result of the damaged muscle tissue. Contrary to this expectation, the reported soreness actually improved from  $2.7 \pm 1.1$  during the preparatory phase to  $3.7 \pm 0.8$  in the eccentric phase. Such improvement may indicate that the program was effective at improving strength but insufficient to cause soreness.

Inspection from individual data can also be used to inform specific program adjustments. Each athlete presents with unique genetic and historical characteristics and are exposed to different outside stressors. Therefore, a training load that leads to an optimal outcome in one athlete may be insufficient or excessive for another athlete (21, 23). While not the focus of the current investigation, examining the raw data revealed that the only athlete to report lower wellness scores in the eccentric, strength & power, and recovery phases compared to baseline also experienced the second largest drop in CMJ5 peak velocity ( $-0.63 \text{ m s}^{-1}$ ), a sign that the athlete may have maladapted to the program as a whole. For this athlete, the largest decrements in wellness came largely from changes in stress and mood, which could have origins outside of the training program. That athlete departed from the trends of the overall team as a whole and such an observation may, in essence, highlight the value of regular monitoring.

Although participants were instructed on how to perform the CMJ5 test beforehand, we did not coach them during any of the evaluations. Participants were only instructed on how to perform the jumps, but were not verbally encouraged during performance to control for external motivation or changes in technique. Accumulated lower body fatigue may have caused participants to slightly alter their technique (e.g. excessive trunk action) to maintain maximal performance. Our only attempt to control for this compensation was to have participants' hands on their hips to eliminate arm action. Also, performances were not publicly displayed to avoid setting up a competition. Given the variability with the CMJ (e.g.,  $\sim 6\%$ ), researchers using linear

position transducers to screen for changes in neuromuscular status should consider examining a less biomechanically complex task.

The time required to perform certain self-report measures of wellness may preclude their regular use in team sport settings. Although lengthy questionnaires can increase internal consistency reliability, the time a S&C professional has with an athlete is often limited. Shorter questionnaires, therefore, offer an opportunity to provide valuable information about the athlete's state without requiring excessive time. We used a short 5-item instrument that tended to have good or very good internal consistency reliability depending upon the phase of training. The wellness rating itself was consistent and worthy of future examination.

We were constrained to a 6-week off-season training schedule due to the academic schedule and climate. Future researchers may want to consider longer training cycles, periodically testing performance measures, or daily measures of velocity or power during a task with less biomechanical complexity than the CMJ. Integrating additional monitoring domains such as sleep, nutrition/hydration, heart rate variability, and academic standing are also interesting points of focus for future research.

The CMJ5 exhibited too high of a typical error to confidently determine a change in neuromuscular status. Other jump tests or neuromuscular evaluations for monitoring overreaching and performance may be suitable. Although the five-item wellness questionnaire demonstrated consistency and efficiency, it did not reflect positive or negative changes in performance. That said, such a simple tool may be helpful in identifying individual maladaptating athletes.

The present study evaluated the utility of a short wellness questionnaire and CMJ with concentric velocity monitoring during a 6-week off season S&C program. Our findings illustrate the short wellness questionnaire comprised of 5 items, demonstrated good internal consistency reliability. The ~6% variability of the CMJ would indicate a need to identify a more consistent exercise for monitoring neuromuscular function with velocity measures.

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