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Returners Exhibit Greater Jumping Performance Improvements During a Peaking Phase Compared With New Players on a Volleyball Team

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ABSTRACT

Purpose: To determine if jumping performance changes during a peaking phase differed between returners and new players in a female collegiate volleyball team and to determine which variables best explained the variation in performance changes. ***Methods:*** Fourteen volleyball players were divided into two groups: returners (n=7) and new players (n=7) who completed a 5-week peaking phase prior to conference championships. Players were tested at baseline prior to the pre-season on measures of vastus lateralis cross-sectional area using ultrasonography, estimated back squat one repetition maximum (1-RM), and countermovement jump height (JH) and relative peak power (PPa) on a force platform. Jumping performance, rating of perceived exertion training load, and sets played were recorded weekly during the peaking phase. ***Results:*** There were moderate to very large ($p<0.01$, Glass's $\Delta=1.74$), and trivial to very large ($p=0.07$, $\Delta=1.09$) differences in JH and PPa changes in favor of returners over new players during the peaking phase, respectively. Irrespective of group, 7 of 14 players achieved peak JH two weeks after the initial overreach. The number of sets played ($r=0.78$, $p<0.01$) and athlete's pre-season relative 1-RM ($r=0.54$, $p=0.05$) were the strongest correlates of JH changes during the peaking phase. ***Conclusions:*** Returners achieved greater improvements in jumping performance during the peaking phase compared to new players, which may be explained by the returners' greater relative maximal strength, time spent competing, and training experience. Thus, volleyball and strength coaches should consider these factors when prescribing training during a peaking phase to ensure their players are prepared for important competitions.

Keywords: jump height, peak power, muscle cross-sectional area, strength, training load

INTRODUCTION

A primary objective of sport science research is to determine what characteristics distinguish between high and low level performers in a sport. Coaches can then target modifiable characteristics to try to improve an athlete's sport performance. In volleyball, higher level performers (e.g. elite, national) are taller, older, have lower body fat percentages, and exhibit greater spike velocities, jump height (JH), impact heights, maximal aerobic power, and motor coordination compared to lower level performers (e.g. collegiate, novice).[1-5] As a result, researchers have recommended that coaches train the modifiable characteristics to improve the performances of junior volleyball players.[1] However, while these studies provide useful descriptive and performance differences between various levels of volleyball players, they do not address differences in the adaptive responses to training. In one of the few studies addressing this in volleyball players, Fry et al.[6] found starters and non-starters on a collegiate female volleyball team exhibited similar improvements in fat free mass, vertical JH, one-repetition maximum (1-RM) squat and hang power clean following an off-season strength and conditioning program. Although empirical evidence is lacking, differences in adaptive responses may be observed between players on a team during specific training phases (e.g. overreaching and tapering).

One of the most important training phases during the competitive season is the peaking phase. The peaking phase in team sports is often comprised of an overreaching period (1-3wks) followed by a taper (1-4wks).[7-9] However, there is a paucity of research on peaking for team sport athletes, which has been attributed to difficulties such as long competitive periods, multiple important competitions in close succession, and difficulty in quantifying training load and sport performance.[10,11] A limitation of previous studies with team sport athletes is that the peaking phase is often not conducted during the athlete's competitive season. Instead it is designed as part of an experimental study conducted during the off-season or pre-season. While these studies provide useful information about athlete's adaptive responses to periods of reduced training, they do not address exactly how athletes prepare for important competitions. Furthermore, differences in recovery-adaptation between players on a team can impact team success during the peaking phase. Also, differences may exist between players on the timing of peak performance during the peaking phase. Thus, research on peaking for volleyball should examine differences between player responses based on experience level (e.g. new players vs. returners) and not solely examine the team mean response. Importantly, any differences in recovery-adaptation that may exist between new players and returners could inform coaches on how to prescribe training for these players during the peaking phase.

Previous research has used countermovement or squat jumps to monitor recovery-adaptation during a peaking phase in rugby, [12,13] futsal,[7] judo,[14] and volleyball players.[8] Strong, positive relationships have been observed between countermovement JH and volleyball performance indicators (spike velocity, spike jump reach, impact height, and athlete's level of achievement).[3,15,16] Therefore, weekly countermovement jump testing during the peaking phase can provide an indication of volleyball player's neuromuscular status and elucidate possible differences in preparedness between players on a team. Yet, it is unknown whether differences in peaking phase responses exist between players on a team. Thus, the purpose of this investigation was to determine if jumping performance changes during a peaking phase differed between returners and new players in a female collegiate volleyball team and to determine which variables best explained the variation in performance changes.

METHODS

Subjects

Fourteen National Collegiate Athletic Association (NCAA) division I volleyball players completed the study and were divided into 2 groups: returners (n=7, age: 20.66±0.89y, body mass: 68.67±3.69kg, height: 176.14±6.82cm) and new players (n=7, 18.82±0.97y, 72.86±10.58kg, 176.43±6.95cm). The returners had 1 to 3 years of experience playing on the team. All players had at least 1y of weight-training experience and received no nutritional supplements during the study. The athletes were also instructed to eat a consistent diet throughout the study; however, this was not directly quantified. The players did not have any recent (<12mon) lower extremity injuries that may have affected performance outcomes. Prior to data collection, the players received information about study's purpose and provided written informed consent. The study was approved by the university's institutional review board for testing of human subjects in accordance with the Helsinki Declaration.

Design

The study was performed as part of an ongoing athlete-monitoring program while the players were preparing for conference championships. Players arrived to the laboratory on seven occasions over a 16-wk period: baseline (T_0), peaking phase (T_1-T_5) and active rest (T_6). Testing was conducted at the beginning of the week at the same time of day (07:00-09:00) for all testing sessions. Players were instructed to refrain from practicing, strength training, and caffeine (≥24h), and to arrive to the laboratory in a fully rested, hydrated state. Baseline testing was conducted prior to the pre-season to examine initial differences between groups. Countermovement jump testing was conducted weekly during the peaking phase to examine changes within and between groups relative to the first week of the peaking phase (T_1). During the baseline testing session players were tested on measures of body mass, body fat percentage, vastus lateralis cross-sectional area (CSA), JH, and peak power allometrically scaled for body mass (PPa=W·kg$^{-0.67}$). Additionally, player’s back squat 1-RM was estimated from the Epley equation[19] using player’s heaviest set of 3 repetitions during the back squat from wk2 training.

Methodology

Training

Training was structured using a block periodization model comprised of sequenced phases: strength, strength-speed, strength, peaking phase, and active rest (Table 1). The goal was to increase maximal strength and power through a combination of traditional strength training and weightlifting exercises using percentage of RM values for sets and repetitions to calculate loads. Strength training was conducted 1-2d/wk during the season with most weeks consisting of 3-4 practice sessions and 2-3 competitions. The first 2wks were part of the specific preparation phase and the following 13wks were part of the competitive season. The focus of this study was the peaking phase, which was the final 5wks of training (wks11-15) prior to conference championships. Training during the peaking phase began with an overreaching microcycle (wk11) prior to reducing training volumes during the taper (wks12-14). The week of conference championships (wk15), a second short overreach was implemented for the first 2 training days followed by 3 lighter training days.

Training Load

Internal training load was estimated using session rating of perceived exertion collected on a 1-10 scale. Rating of perceived exertion was multiplied by the duration of the session (min) to form a rating of perceived exertion training load (RPETL) for practice and strength training sessions.[17] Additionally, player's sets played in each match during the peaking phase were recorded and used for correlational analyses. Strength training volume-load (VL) was recorded weekly for all barbell lifts and was calculated by multiplying the mass of the external load by the number of repetitions.[18]

Anthropometrics

Body mass was measured using a digital scale (Tanita B.F. 350, Tanita Corp. of America, Inc., Arlington Heights, IL), and body fat percentage was estimated from the sum of 7 skinfolds using a skinfold caliper (Lange, Beta Technology Inc., Cambridge, MD).[20] All anthropometrics were measured at the same time of day by the same experienced technician for all testing sessions.

Muscle Cross-Sectional Area

A 7.5 MHz ultrasound probe (LOGIQ P6, General Electric Healthcare, Wauwatosa, WI) was used to measure CSA of the vastus lateralis by the same experienced technician (>500 ultrasound scans with athletes) for all testing sessions. The players laid on their left side with their hips perpendicular to the examination table in the axial plane with a knee angle set at 120º as measured by a goniometer. Sampling location for the vastus lateralis was 50% of the femur length measured as the distance between the greater trochanter and the lateral epicondyle of the femur.[21] The location was marked with a permanent marker and the ultrasonography probe was covered with water-soluble transmission gel to aid acoustic coupling and avoid depression of the skin. Vastus lateralis CSA was measured by placing the probe perpendicular to the muscle and moving it in the transverse plane to collect a cross-sectional image using the LOGIQView function of the ultrasound device. Vastus lateralis CSA was measured by tracing the inter-muscular interface in the cross-sectional images using the measurement function of the ultrasound device. Relative CSA was calculated by allometrically scaling for body mass (CSAa). The mean of three images was used for analysis. Repeated measurements yielded an intraclass correlation coefficient (ICC)=0.98, and a coefficient of variation (CV)=2.72% for CSA.

Countermovement Jumps

Following a consistent dynamic warm-up, countermovement jumps were measured using dual force plates affixed side by side with a sampling frequency of 1000Hz (Rice Lake Weighing Systems, Rice Lake, WI). Countermovement jumps were performed while holding a plastic pipe across the shoulders to prevent arm swing. Countermovement jumps were performed during baseline testing and were performed weekly during the peaking phase. For the countermovement jumps, players were instructed to first remain stable in an upright position. Once the force-time trace was stable the tester shouted "3,2,1...jump!" and the athlete performed a maximal countermovement jump with a self-selected depth. All jump trials were recorded and analyzed using a custom program (LabView 2010, National Instruments Co., Austin, TX). Jump height was estimated from flight time as described previously.[22] The force-time trace was converted to an acceleration-time trace, which was then differentiated to obtain a velocity-time trace. Peak power was the maximal value obtained from the product of the velocity-time and force-time trace. The mean of the two best trials within a 2cm difference in JH was used for analysis. Additional trials were performed when the difference between two trials was greater than 2cm. The week that each athlete achieved their peak JH during the peaking phase and the change in JH from T_1 to peak (supercompensation) were determined for further analyses. Repeated measurements yielded an ICC=0.98, 0.95, and a CV=2.20%, 2.31% for JH and PPa, respectively.

Statistical Analyses

After data were scanned for outliers, normality and homogeneity of between-group variance were assessed using a Shapiro-Wilks and Levene's test, respectively. Group baseline data were compared using an independent samples t-test. Peaking phase countermovement jump and training load data were analyzed using a 2x6 (group by time) mixed analysis of variance (ANOVA) to determine within and between group differences in changes. Simple main effects were followed by post-hoc comparisons using a Benjamini-Hochberg adjustment. Magnitude of within-group changes and between-group differences in changes were determined using Glass's Δ with 90% confidence intervals (CI).[23] Effect sizes with CIs were assessed using the following scale: trivial, 0.0-0.2; small 0.2-0.6; moderate 0.6-1.2; large, 1.2-2.0; very large, 2.0-4.0.[24] Pearson product-moment zero order correlations with 90% CIs were calculated to determine the relationship between variables collected at baseline and JH supercompensation during the peaking phase. Correlation coefficients with CIs were based on the following scale: trivial, ≤0.10; small, 0.10–0.3; moderate, 0.30–0.5; large, 0.50–0.70; very large, 0.70–0.90; and nearly perfect, ≥0.90. Tests with p-values ≤0.05 were considered statistically significant, and tests with p-values between 0.051 and 0.10 were deemed nearly statistically significant. Analyses were performed using SPSS software version 23 (IMB Co., New York, NY, USA), and Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA, USA).

RESULTS

Baseline

There was a large to very large, statistically significant difference in age with returners being older than new players (p<0.001, Δ=1.89 [1.50,2.28], respectively). There were trivial to large, near statistically significant differences in favor of the returners over new players for vastus lateralis CSAa (1.80±0.22 vs 1.58±0.20cm^2·kg$^{-0.67}$, *p*=0.08, Δ=1.04 [0.06,2.02], respectively). There were moderate to very large, statistically significant differences in favor of returners over new players for back squat 1-RM (85.86±15.63 vs 56.05±16.65kg, *p*=0.005, Δ=1.79 [0.87,2.71]) and 1-RMa (5.11±0.86 vs 3.27±1.07kg·kg$^{-0.67}$, *p*=0.004, Δ=1.71 [0.86,2.56], respectively). There were small to large, statistically significant and trivial to large, near statistically significant differences in favor of returners over new players for JH (*p*=0.03, Δ=1.12 [0.35,1.89]), and PPa (*p*=0.06, Δ=0.94 [0.14,1.73]), respectively (Figure 1).

RPETL and VL

There were no group by time interactions or group effects for any training load variables. There were statistically significant time effects for practice RPETL (F(5,60)=15.83, *p*<0.001), strength training RPETL (F(5,60)=18.67, *p*<0.001), total RPETL (F(5,60)=17.16, *p*<0.001), and strength training VL (F(5,60)=49.72, *p*<0.001). There were statistically significant increases in total RPETL during the first week of the peaking phase (*p*<0.001, Δ=5.41 [4.29,6.54], *p*=0.02, Δ=1.94 [0.72,3.16]), and statistically significant decreases in total RPETL during the third week of the peaking phase compared to in-season training for returners and new players (*p*<0.001 Δ=3.32 [2.79,3.86], *p*<0.001, Δ=2.25 [1.60,2.90]), respectively (Table 2). Additionally, there were statistically significant differences in sets played during the peaking phase with returners playing more than new players (36.14±6.52 vs 22.71±12.28sets, *p*=0.03, Δ=1.09 [0.30,1.88], respectively).

Peaking Phase

There were no group by time interactions for JH and PPa during the peaking phase. There were statistically significant time effects (F(5,60)=3.45, *p*=0.01, F(5,60)=3.70, *p*=0.01) and group effects approached statistical significance (F(1,12)=4.17, *p*=0.06, F(1,12)=3.13, *p*=0.10) for JH and PPa, respectively. Changes in JH for the returners relative to T_1 were trivial to very large at T_2 (p=0.07, Δ=1.19 [0.11,2.26]), small to large (p=0.03, Δ=0.76 [0.21,1.31]) at T_3, moderate to very large (p=0.009, Δ=1.82 [0.89,2.76]) at T_4, and small to large (p=0.03, Δ=1.07 [0.31,1.82]) at T_6. Changes in PPa for the returners relative to T_1 were small to large (p=0.02, Δ=1.02 [0.36,1.69]) at T_4, and moderate to very large (p=0.01, Δ=1.34 [0.60,2.09]) at T_6. Changes in JH and PPa for the new players relative to T_1 were trivial to small (p=0.03, Δ=0.19 [0.06,0.31]) at T_3, and trivial to moderate (p=0.02, Δ=0.44 [0.17,0.72]) at T_4, respectively (Table 3). Between-group differences in change from T_1 for JH favored the returners over the new players and were trivial to very large at T_2 (p=0.10, Δ=1.66 [0,3.36]), large to very large (p=0.002, Δ=2.51 [1.34,3.68]) at T_3, and trivial to very large (p=0.08, Δ=1.07 [0.06,2.07]) at T_4 (Figure 2).

Peak and Nadir Performance

Jump height and PPa supercompensation for the returners were large to very large (p<0.001, Δ=2.41 [1.73,3.09]), and large to very large (p<0.001, Δ=2.00 [1.44,2.56]), respectively. Jump height and PPa supercompensation for the new players were trivial to small (p=0.05, Δ=0.27 [0.05,0.49]), and small to moderate (p=0.004, Δ=0.69 [0.39,0.98]), respectively. Between-group differences in JH and PPa supercompensation favored the returners over the new players and were moderate to very large (p<0.01, Δ=1.74 [0.78,2.70]), and trivial to very large (p=0.07, Δ=1.09 [0.11,2.08]), respectively (Figure 3). Irrespective of group, half of the team achieved peak JH at T_4 (7 of 14) and nadir JH at T_5 (6 of 14) (Figure 4).

Variables explaining JH performance supercompensation

Jump height supercompensation exhibited a large to nearly perfect relationship with sets played during the peaking phase (r=0.78 [0.57,0.99], p=0.003), and a small to very large relationship with athlete's 1-RMa (r=0.54 [0.19,0.89], *p*=0.05). There was a trivial to very large non-statistically significant relationship between sets played during the peaking phase and 1-RMa (r=0.44 [0.05,0.83], *p*=0.12). Additionally, 1-RMa exhibited a large to nearly perfect relationship with CSAa (r=0.78 [0.57,0.99], *p*=0.001).

DISCUSSION

The purpose of this investigation was to determine if performance changes during a peaking phase differed between returners and new players in a female collegiate volleyball team and to determine which variables best explained the variation in performance changes. The primary results of this investigation include: a) large to very large differences in age, trivial to large differences in vastus lateralis CSAa, trivial to very large differences in relative maximal strength and countermovement jump performance in favor of returners over new players at baseline, b) moderate to very large, and trivial to very large differences in JH and PPa supercompensation in favor of returners over new players during the peaking phase, respectively, c) number of sets played during the peaking phase and athlete's baseline back squat 1-RMa were the strongest correlates of JH supercompensation during the peaking phase.

The baseline testing results demonstrate that the returners were older, had greater absolute and relative maximal strength, and countermovement jump performance. These results are in agreement with research demonstrating that maximal strength, JH, and power output are different between starters and non-starters and between different levels of volleyball players.[1,3-5,16] A result unique to this study is the greater relative vastus lateralis CSA observed in the returners compared to the new players at baseline. This may partially explain the superior relative maximal strength and jumping performance results for the returners.

In the only other published study examining peaking phase responses in volleyball players, Freitas et al.[8] found significantly greater creatine kinase, RPETL, training monotony, and training strain in half a team of male volleyball players who performed an 11-d overreach compared to the other half of the team who continued with normal training. The authors concluded that countermovement jump performance should not be used to evaluate training adaptations in volleyball players because no significant within-group changes were observed in JH during the overreach or the 14-d taper that followed. In contrast, we found large to very large, and trivial to small increases in JH during the peaking phase for the returners and new players, respectively. The differences between the previous study and the present study, may have been due to differences in how JH was measured (contact mat vs. uniaxial force plates), the caliber of players (national vs. collegiate level), and the training program. Previous research has demonstrated that mechanistic variables (e.g. rate of force development, stretching phase duration, acceleration-propulsion phase shape factor) obtained from the force-time trace may provide a more comprehensive assessment of training adaptations than instantaneous variables (e.g. peak power, peak force) alone.[25] We conclude, given the appropriate instrumentation, countermovement jump performance can be used to monitor training adaptations in volleyball players and that future athlete monitoring research should give greater attention to mechanistic variables.

Despite differences in between group changes, the within group changes relative to T_1 followed a similar pattern in returners and new players. In support of this, peak and nadir JH occurred at similar time points in both groups (T_4 and T_5, respectively) with half of the team achieving peak JH two weeks after the initial overreach. These findings agree with the meta-analysis results from Bosquet and colleagues,[26] who demonstrated that peak endurance performance occurred after 2wks of tapering and diminished after 3wks of tapering. The athlete's competition schedule may also explain the timing of peak and nadir performance. The team played their two worst opponents the week prior to their best jumping performance, and their two best opponents the week prior to their worst jumping performance. Previous research has demonstrated that volleyball matches induce significant increases in blood lactate, and reaction time, and decreases in knee joint position sense resulting in decreased sensorimotor system acuity.[27,28] It is possible that the rest period between matches and weekly jump testing sessions was insufficient to completely dissipate fatigue effects of play. Additional confounding variables explaining the timing of peak and nadir performance may include psychological readiness, nutritional status, and other external stressors (e.g. school, relationships, job).

Both returners and new players perceived total training load to be more difficult during the initial overreach and lighter during the second week of the taper compared to in-season training. Despite these similarities, the weekly countermovement jump data demonstrate that the returners consistently achieved greater JH improvements compared to the new players. These findings beg the question, which variables best explain the variation in JH supercompensation response? Considering the correlational results, a possible explanation is that players who played more sets during the peaking phase and had greater relative maximal strength possessed greater fatigue resistance, which enhanced their recovery-adaptation during the peaking phase. In support of this, previous research has demonstrated that stronger individuals have greater fatigue resistance at a given absolute workload as an adaptation to repetitive high load training.[29] Another important consideration is that returners in this investigation were accustomed to periodized training from previous seasons with the team, whereas new players were introduced to periodized training at the beginning of the pre-season. Considering the acute inflammatory response is related to the novelty of the training stimulus and is attenuated following successive bouts of similar training,[30] it is possible the returners were better able to tolerate training during the peaking phase due to a repeated bout effect.

PRACTICAL APPLICATIONS

These results suggest that training prescription during the peaking phase should differ between players based on their relative maximal strength, time spent competing, and training experience. Thus, volleyball and strength coaches should consider these factors when prescribing training during a peaking phase to ensure their players are prepared for important competitions. Additionally, countermovement jumps performed on a force platform can be used to monitor training adaptations in volleyball players and inform training prescription during a peaking phase.

A few limitations of this study, albeit difficult in practice, were the lack of a control group and small sample size. Future research should develop a model to determine the unique contribution of predictor variables (e.g. relative maximum strength, training load, fatigue resistance) to performance supercompensation during a peaking phase in volleyball players.

CONCLUSIONS

In summary, these findings demonstrate that differences in muscle morphology, relative maximal strength, and countermovement jump performance exist between returners and new players on a female collegiate volleyball team. Returners achieved greater countermovement jump performance supercompensation during the peaking phase compared to new players. This appeared to be related to the returners' greater number of sets played during the peaking phase and relative maximal strength. These findings suggest that returners possessed greater fatigue resistance, which resulted in greater jumping performance improvements compared to new players during the peaking phase.

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REFERENCES

1. Gabbett T, Georgieff B. Physiological and anthropometric characteristics of Australian junior national, state, and novice volleyball players. *J Strength Cond Res.* 2007;21(3):902-908.

2. Stamm R, Stamm M, Thomson K. Role of adolescent female volleyball players' psychophysiological properties and body build in performance of different elements of the game. *Percept Mot Skills.* 2005;101(1):108-120.

3. Pion JA, Fransen J, Deprez DN, et al. Stature and jumping height are required in female volleyball, but motor coordination is a key factor for future elite success. *J Strength Cond Res.* 2015;29(6):1480-1485.

4. Fleck SJ, Case S, Puhl J, Van Handle P. Physical and physiological characteristics of elite women volleyball players. *Can J Appl Sport Sci.* 1985;10(3):122-126.

5. Smith DJ, Roberts D, Watson B. Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *J Sports Sci.* 1992;10(2):131-138.

6. Fry AC, Kraemer WJ, Weseman CA, et al. The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *J Strength Cond Res.* 1991;5(4):174-181.

7. Claudino JG, Cronin JB, Mezencio B, et al. Auto-regulating jump performance to induce functional overreaching. *J Strength Cond Res.* 2016;30(8):2242-2249.

8. Freitas VH, Nakamura FY, Miloski B, Samulski D, Bara-Filho MG. Sensitivity of physiological and psychological markers to training load intensification in volleyball players. *J Sports Sci Med.* 2014;13(3):571-579.

9. Coutts A, Reaburn P, Piva TJ, Murphy A. Changes in selected biochemical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. *Int J Sports Med.* 2007;28(2):116-124.

10. Pyne D, Mujika I, Reilly T. Peaking for optimal performance: research limitations and future directions. *J Sports Sci.* 2009;27(3):195-202.

11. Mujika I. Challenges of team-sport research. *Int J Sports Physiol Perform.* 2007;2(3):221-222.

12. Gibson NE, Boyd AJ, Murray AM. Countermovement jump is not affected during final competition preparation periods in elite rugby sevens players. *J Strength Cond Res.* 2016;30(3):777-783.

13. de Lacey J, Brughelli M, McGuigan M, Hansen K, Samozino P, Morin JB. The effects of tapering on power-force-velocity profiling and jump performance in professional rugby league players. *J Strength Cond Res.* 2014;28(12):3567-3570.

14. Papacosta E, Gleeson M, Nassis GP. Salivary hormones, IgA, and performance during intense training and tapering in judo athletes. *J Strength Cond Res.* 2013;27(9):2569-2580.

15. Forthomme B, Croisier JL, Ciccarone G, Crielaard JM, Cloes M. Factors correlated with volleyball spike velocity. *Am J Sports Med.* 2005;33(10):1513-1519.

16. Sheppard JM, Cronin JB, Gabbett TJ, McGuigan MR, Etxebarria N, Newton RU. Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. *J Strength Cond Res.* 2008;22(3):758-765.

17. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15(1):109-115.

18. Haff G. Quantifying workloads in resistance training: a brief review. *Strength Cond J.* 2010;10:31-40.

19. Epley B. Poundage chart. *Boyd Epley Workout:*. Lincoln, NE: Body Enterprises; 1985:86.

20. Ball SD, Altena TS, Swan PD. Comparison of anthropometry to DXA: a new prediction equation for men. *Eur J Clin Nutr.* 2004;58(11):1525-1531.

21. Howe TE, Oldham JA. The reliability of measuring quadriceps cross-sectional area with compound B ultrasound scanning. *Physiother Res Int.* 1996;1(2):112-126.

22. Linthorne NP. Analysis of standing vertical jumps using a force platform. *Am J Phys.* 2001;69(11):1198-1204.

23. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol.* 2013;4:863.

24. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009;41(1):3-13.

25. Cormie P, McBride JM, McCaulley GO. Power-time, force-time, and velocity-time curve analysis of the countermovement jump: impact of training. *J Strength Cond Res.* 2009;23(1):177-186.

26. Bosquet L, Montpetit J, Arvisais D, Mujika I. Effects of tapering on performance: a meta-analysis. *Med Sci Sports Exerc.* 2007;39(8):1358-1365.

27. Ribeiro F, Santos F, Gonçalves P, Oliveira J. Effects of volleyball match-induced fatigue on knee joint position sense. *Eur J Sport Sci.* 2008;8(6):397-402.

28. Mroczek D, Kawczyński A, Chmura J. Changes of reaction time and blood lactate concentration of elite volleyball players during a game. *J Hum Kinet.* 2011;28:73-78.

29. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. *Sports Med.* 2016;46(10):1419-1449.

30. Nosaka K, Clarkson PM. Muscle damage following repeated bouts of high force eccentric exercise. *Med Sci Sports Exerc.* 1995;27(9):1263-1269.

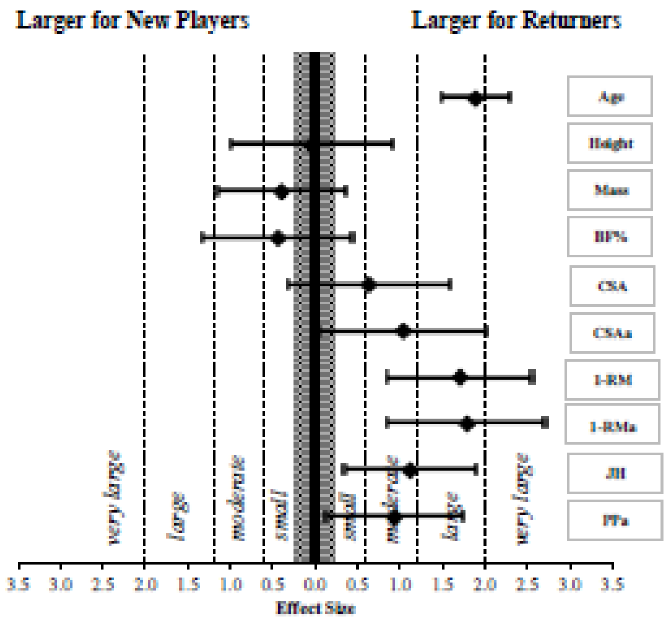

Figure 1: Differences between groups at T_0 in descriptive and performance characteristics. BF%- body fat percentage, CSAa-cross-sectional area, CSAa-relative cross-sectional area, 1-RM-estimated back squat 1-repetition maximum, 1-RMa-estimated relative back squat 1-repetition maximum, JH-jump height, PPa-relative peak power

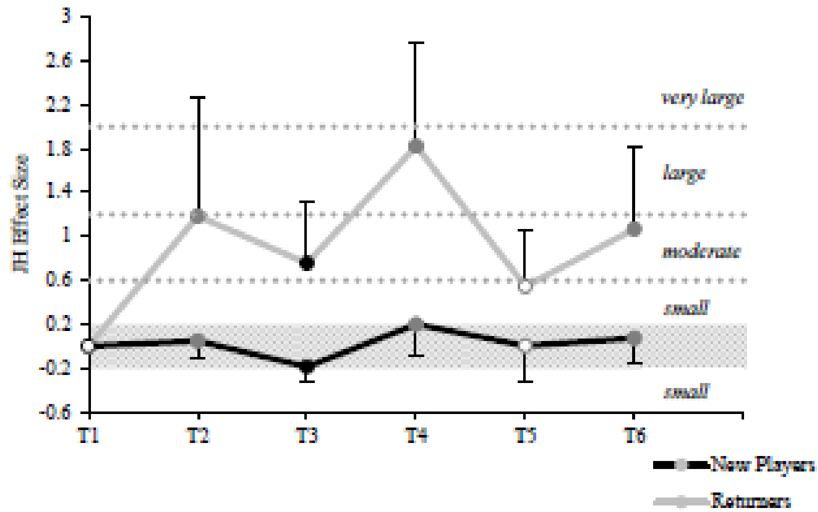

Figure 2: Within-group changes and differences in between-group changes in JH relative to T_1. Changes are reported as (Δ±90%CI). White color marker indicates no between-group difference in change from T_1; grey color marker indicates trivial to very large; black indicates large to very large. JH-jump height.

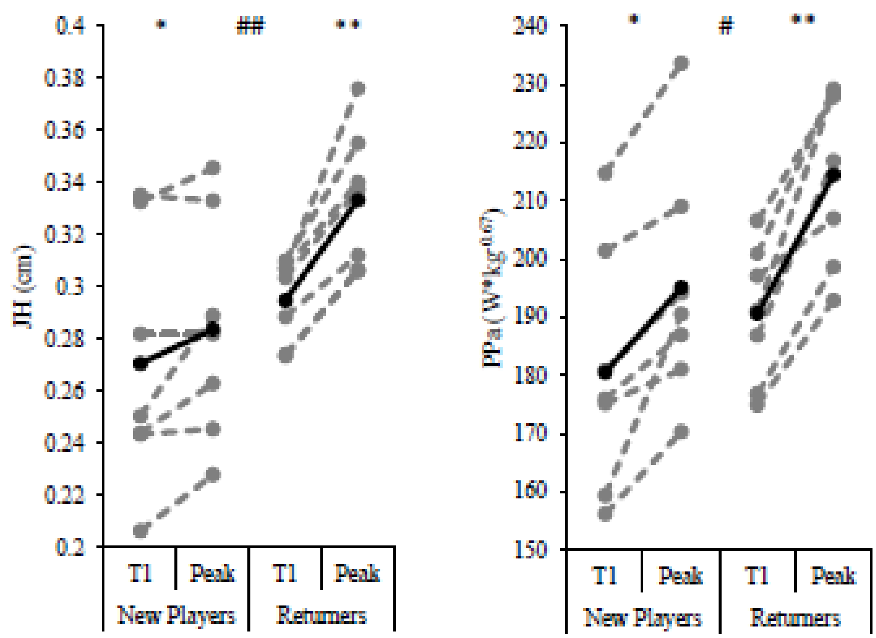

Figure 3: Group JH and PPa supercompensation during the peaking phase. Within group change relative to T_1: *$p \leq 0.05$, **$p \leq 0.001$. Difference in between-group changes relative to T_1: #$p \leq 0.10$, ##$p \leq 0.05$. Gray dashed lines are individual changes and black lines are group mean changes. JH-jump height, PPa-relative peak power

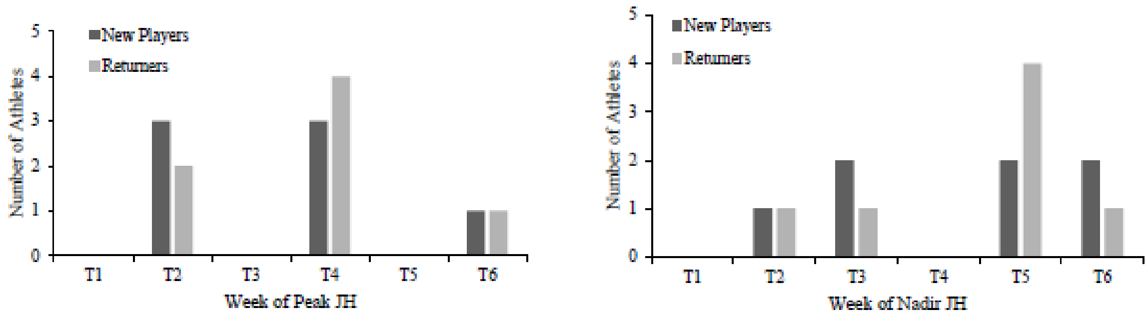

Figure 4: Occurrence of individual JH peak and nadir week during the peaking phase. JH- jump height.

"Returners Exhibit Greater Jumping Performance Improvements During a Peaking Phase Compared to New Players on a Volleyball Team" by Bazyler CD et al.
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Table 1: Strength training program

Week	Testing	Phase	Frequency (days/week)	SetxRep	Relative Training Intensity	Exercises	Competitions
Week1	T_0	Strength	2	3x3 (1x5)	MH (85-90%)	BS, SLDL, BP, BOR	
Week2			2	3x3 (1x5)	H (90-95%)		
Week3			2	3x3 (1x5)	ML (75-80%)		$,$,$
Week4			2	3x3 (1x5)	M (80-85%)		$,$,$
Week5			2	3x3 (1x5)	MH (85-90%)		$,$,$
Week6		Strength-Speed	2	3x5, 3x3 (1x5)	MH (80-85%)	BS, CPK, IBP, PU	$,$,$
Week7			1	3x3 (1x5)	L (70-75%)		$,$$,$
Week8			2	3x3 (1x5)	L (70-75%)		$$,$
Week9		Strength	2	3x5, 3x3 (1x5)	MH (85-90%)	BS, SLDL, BP, PU	$$
Week10			1	3x3 (1x5)	VL (65-70%)		$,$$,$
Week11	T_1	Peaking Phase	2	5x5, 3x3 (1x5)	M (80-85%)	BS, SLDL, IBP, BOR	$,$
Week12	T_2		2	3x3 (1x5)	L (70-75%)		$$,$
Week13	T_3		2	3x3 (1x5)	L (70-75%)		$,$$
Week14	T_4		2	3x5, 3x3 (1x5)	M (80-85%)		$$,$$
Week15	T_5		2	5x5, 3x5	H (90-95%)	BS, 1/2 BS, SLDL, MTP, BP, PU, 1ADBR	$$$,$$$
Week16	T_6	Active Rest	0	did not lift			

BOR-bent over row, BP-bench press, BS-back squat, CPK-clean pull from knee, IBP-incline bench press, MTP-mid-thigh pull, PU-pull-up, SLDL-stiff-legged deadlift, 1ADBR-one arm dumbbell row; H-heavy, MH-moderately heavy, M-moderate, ML-moderately light, L-light, VL-very light; competitions: $low importance, $$moderate importance, $$$high importance

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Table 2: Changes in weekly average RPETL and strength training VL during the peaking phase relative to in-season training (mean±SD)

	Training Phase	**In-season**	**Peaking Phase**				
	Week	**1-10**	**11**	**12**	**13**	**14**	**15**
New Players	Strength Training RPETL (A.U.)	275±109	367±130	117±64**	437±162*	409±121*	688±216**
	Practice RPETL (A.U.)	1302±364	1831±575*	1830±1051	438±74**	329±278**	803±722
	Total RPETL (A.U.)	1577±420	2198±555**	1947±1075	875±187**	739±279**	1491±903
	Strength Training VL (kg)	5743±524	8313±809**	5350±566	6140±692	6162±973	11893±1110**
Returners	Strength Training RPETL (A.U.)	222±45	356±149	196±40	248±110	331±121*	570±296**
	Practice RPETL (A.U.)	1096±164	2041±454**	1441±493	353±57**	748±401*	1032±406
	Total RPETL (A.U.)	1318±185	2296±396**	1525±559	601±109**	1078±468	1602±658
	Strength Training VL (kg)	5494±1655	7810±2542*	5185±1102	5636±1163	5511±2053	9533±3242**

Within group changes relative to In-season phase: *p≤0.10, **p≤0.05. RPETL-rating of perceived exertion training load, VL-volume-load

Table 3: Weekly JH and PPa during the peaking phase (mean±SD).

	Testing Week	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
Returners	JH (m)	0.29±0.02	0.31±0.03*#	0.31±0.02**##	0.32±0.03**#	0.30±0.02*	0.31±0.03**
	PPa ($W·kg^{-0.67}$)	190.66±11.90	199.62±13.57	197.20±15.72*	202.85±19.28**	196.01±13.08*	206.66±16.98**
New Players	JH (m)	0.27±0.05	0.27±0.04	0.26±0.05**	0.28±0.05	0.27±0.04	0.27±0.04
	PPa ($W·kg^{-0.67}$)	180.58±21.18	185.49±16.74	181.94±16.60	189.90±24.25**	180.97±16.14	187.15±18.17

Within group changes relative to T_1: *p≤0.10, **p≤0.05. Difference in between-group changes relative to T_1: #p≤0.10, ##p≤0.05. JH-jump height, PPa-peak power allometrically scaled for body mass