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Applying a Cluster-Analysis Approach to Monitor Training Load in Male Volleyball During the Preseason Period

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Purpose: This study aimed to (1) classify the external-load measures carried out during the preseason period by male volleyball players via cluster technique identifying the most important external-load measures and (2) assess the differences between clusters in internal-load variables. ***Methods:*** Twenty-two male Division 1 and 2 volleyball players (mean [SD] age 21.2 [3.0] y, stature 186.4 [6.0] cm, body mass 80.0[10.5 kg]) were recruited for this study. Players' external (jump, player load, acceleration, deceleration, and change of direction) and internal (percentage of peak heart rate, summated heart-rate zones, and session rating of perceived exertion) loads were monitored during 5 weeks of the preseason period for both Division 1 and Division 2 teams. External-load measures were classified via a 2-step cluster analysis followed by predicting importance analysis, while differences in internal-load measures between clusters were analyzed using linear mixed models. ***Results:*** The 3 identified clusters classified the sessions in high (C1, 30.1%) moderate (C2, 31.8%), and low (C3, 38.1%) load. Predicting importance analysis found jump as the main cluster predictor (predicting value = 1), followed by player load (predicting value = 0.73). An effect of cluster was found on each internal-load measure ($P < .001$), with post hoc analyses showing lower values in C3 compared with C1 and C2 ($P < .05$, effect sizes ranges from small to moderate). ***Conclusions:*** Volleyball coaches can adopt a monitoring system including cluster analysis to classify the preseason training sessions' load having a higher consideration for jump and player load as the main external-load measures.

Keywords: inertial measurement unit, jump, player load, sRPE load, workload

Having a full understanding of the training process is one of the main goals for team-sport coaches and practitioners. In the last few years, a theoretical framework of the training process has been developed[1] in which the fundamental role played by training load is emphasized. In its constitutive definition, training load has been classified as external and internal, with external load referred to "what the athlete does" and can be observed during the training and internal load indicating the internal responses the body experiences by the athletes during the training session.[1] Monitoring and understanding both external and internal loads are fundamental for the coaching staff since they can help in identifying whether the planned workload induced the expected adaptation across the training process. This process applies to all team sports including net sports such as volleyball.

Volleyball is a team sport characterized by an intermittent nature, with short and high-intensity explosive efforts.[2] In preparation for the matches scheduled during the in-season period, volleyball teams are usually undergoing some weeks of intensified training across the preseason period aiming at enhancing the physical, technical, and tactical performance of the athletes. Monitoring the external and internal loads is particularly important during the preseason period, which encompasses higher load compared with the other parts of the season.[3–6] For instance, evaluating the loads carried out by players during the training process can help in adjusting the program based on individual needs.

External load in volleyball can be assessed using inertial movement units (IMUs), which are constituted of triaxial accelerometers, gyroscopes, and magnetometers. These devices can derive some typical measures of external load executed during volleyball practices such as jumps, player load (PL; ie, the sum of the accelerations across all axes of the internal triaxial accelerometer divided by a scaling factor of 100),[7] accelerations (ACC), decelerations (DEC), and changes of direction (CoD).[8] Overall, these measures can provide a full picture of the athlete's external load parameters, reporting possible benchmarks for coaches and practitioners. These benchmarks of external load executed during volleyball training sessions can be useful in setting goals for the following in-season period or the next season or in defining the specific amount of load needed to achieve training adaptations.[9] Moreover, it can provide information about how to identify sessions with high and low loads encountered across the various parts of the season.

Cluster analysis, which is a machine-learning unsupervised technique used to divide data into groups of similar clusters, and to present their similarities, and differences[10] has been considered a potential statistical tool to be used to classify training sessions based on load measures. For instance, it has been previously used in team sports, such as basketball,[11] and futsal[3] to identify the intensity zones of various external and internal load measures during match and training sessions to provide potential benchmarks for coaches and practitioners. To the best of the authors' knowledge, no previous investigation utilized cluster technique to classify the load carried out during volleyball preseason phase, suggesting the needs to investigate this area to provide new benchmarks useful for volleyball training.

Clustering together various external load measures can also indicate the best measure predicting the classification. This information might be essential for volleyball coaches, particularly in the era of big data, in which companies providing external load

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monitoring tools can overwhelm clients with a large amount of information. Being able to discriminate the most relevant external load measures differentiating between the load imposed by the various training sessions can help coaches in their monitoring process. Furthermore, it would be interesting to assess whether internal load measures used in volleyball players (eg, heart-rate based measures and session rating of perceived exertion) are influenced by the various clusters of the external load to have a better comprehension of the internal responses to the determined external load. Overall, this analysis can be considered as a new informative approach for volleyball coaches, practitioners, and scientists. Therefore, the aims of this study were to: (1) classify the external load measures carried out during the preseason period by male volleyball players via cluster technique identifying the most important external load measures and (2) assess the differences between clusters in terms of internal load variables.

Methods

Participants

Twenty-four male volleyball players (8 outside hitter, 4 liberos, 4 opposites, 5 middle blockers, and 3 setters) from 2 teams participating in Lithuania national volleyball championships ("Top Sport" Lietuvos Vyrų Tinklinio Čempionatas [Lithuanian Men Volleyball Championship], and "Top Sport" Lietuvos Vyrų Tinklinio 1 Lyga [Lithuanian Men Volleyball 1st league]) during the 2021/22 season were recruited for this study. Players were free from injuries during the preseason period and completed at least 50% of the scheduled sessions. Two players (1 opposite and 1 libero) were excluded from the analysis due to malfunctions of their devices, which did not allow us to obtain their full training data. Consequently, 22 players (mean [SD]; age: 21.2 [3.0] y, stature: 186.4 [6.0] cm, body mass: 80.0 [10.5] kg, training experience: 7.3 [3.8] y) were included in the study. The athletes received clear explanations of the study aim, procedures, possible risks, and benefits before the commencement of the study, providing written consent. Ethical approval was obtained from the Social Science Ethical Committee review board of the Lithuanian Sports University (No. SMTEK-123).

Design

This study lasted 5 weeks of the preseason period (September–October 2021) and involved an observational design. It should be noted that, although this study investigates a new research question, part of the same data set was used previously in another investigation involving different research questions.[8] A total of 29 sessions (15 and 14 for Divisions 1 and 2 team) were monitored encompassing ~3 weekly sessions lasting 88.8 (13.1) minutes. Additionally, Division 1 team undertook 2 weekly strength and conditioning sessions in the gym, which were not monitored in the present study. A final sample of 239 individual datapoints (122 and 117 for Divisions 1 and 2, respectively) were considered for the final analyses. Training sessions were delivered by the coaching staff, while the research staff was only involved in the monitoring process.

Methodology

Players' external loads were monitored during each investigated training session and friendly games. Before each training session and friendly game, each player was required to wear a vest on their upper back, a wearable microsensor with embedded a triaxial accelerometer (T6, Catapult Innovations) sampling at 100 Hz to determine players' number of Jump, CoD (ie, inertial movements registered in a rightward/leftward lateral vector), ACC (ie, inertial movements registered in a forward acceleration vector), and DEC (ie, inertial movements registered in a forward deceleration vector). Moreover, PL, which represents a modified vector magnitude expressed as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the 3 axes (X, Y, and Z) and divided by 100, was used as external load measure. PL and the other IMUs showed a good reliability in team sports,[12] and were previously used in team sports[13] and specifically in volleyball.[8] The same device for each participant was used to monitor external load during data collection to avoid any possible problems of interunit reliability.

To monitor objective internal loads, players were wearing heart rate (HR) chest belts (Polar H10, Polar Electro) during each monitored session. Players' peak HR was defined as the highest value recorded across the monitored sessions. Successively, the HR measure was expressed as percentage of the HR peak (%HRpeak). Furthermore, the summated heart rate zone (SHRZ) was calculated based on Edwards's model[14,15] as follows: SHRZ = (duration [in minutes] in zone 1×1) + (duration in zone 2×2) + (duration in zone 3×3) + (duration in zone 4×4) + (duration in zone 5×5), where zone 1 = 50.0% to 59.9% of HRpeak, zone 2 = 60.0% to 69.9% HRpeak, zone 3 = 70.0% to 79.9% HRpeak, zone 4 = 80.0% to 89.9% HRpeak, and zone 5 = 90.0% to 100% HRpeak. All internal and external load data were processed using OpenField software (version 1.18, Catapult Innovations) and downloaded for further statistical analysis. Resting breaks or pauses during training sessions (ie, between-drill and water breaks and drill explanations), and friendly games (ie, time-outs, breaks between sets, etc) were not included into the data analysis, while within-drill breaks during training sessions and within-set breaks during games were included in the analysis.

At around 20 minutes after the completion of the training sessions or friendly games, players were required to evaluate their perceived exertion using the rating of perceived exertion scale.[16] Specifically, players were answering the question "How hard was your workout?" using the CR10 Borg scale modified by Foster,[16] which ranges from 0—"Rest" to 10—"Maximal." Successively, session rating of perceived exertion (sRPE-load) was obtained multiplying the total exercise duration (in minutes) by the rating of perceived exertion value. This method has previously been used in volleyball[17] and showed a strong relationship with objective internal load measures.[18]

Statistical Analysis

Mean, SD, minimum, and maximum were calculated as descriptive statistics for each external load variable. A 2-step cluster analysis was used to group the external load measures (ie, PL, Jumps, CoD, ACC, and DEC) using a fixed number of 3 clusters (high, moderate, and low loads). For the cluster formation, the analysis of Silhouette measure of cohesion and separation was also performed with values interpreted as 0.0 to 0.2, poor; 0.2 to 0.8, fair; and 0.8 to 1, high.[19]

Afterward, separated linear mixed models (LMMs) were used to assess differences between the 3 identified clusters for each internal load measure (ie, %HRpeak, SHRZ, and sRPE-load), including cluster as fixed effect, and player as random effect. In the case of statistically significant difference, post hoc analyses were performed using the Bonferroni correction. Moreover, for each pairwise comparison, Cohen *d* effect sizes were also calculated with 95% confidence intervals and interpreted as follows: trivial ≤0.20, small = 0.20 to 0.59, moderate = 0.60 to 1.19, large = 1.20 to 1.99, and very large ≥2.00.[20] The cluster analysis was performed using SPSS software (version 29.0.1, IBM), while linear mixed models and following Bonferroni analyses for post hoc were executed on Jamovi software (version 2.3.21, 2023). An alpha level of $P \leq .05$ was set a priori for statistical significance.

Results

Applying the 2-step cluster analysis and using the Silhouette measure of cohesion and separation, an indicator of 0.3 (fair) was found. The 3 identified clusters classified the sessions in high (cluster 1, C1) moderate (cluster 2, C2), and low (cluster 3, C3) load, which represents the 30.1%, 31.8%, and 38.1% of the total number of individual sessions, respectively. Descriptive statistics of the external load measures for each cluster are shown in Table 1.

The predictor importance analysis highlighted Jump as the main predictor for the clusters (predicting value = 1) followed by PL (predicting value = 0.73), CoD (predicting value = 0.62), ACC (predicting value = 0.56), and DEC (predicting value = 0.51; Figure 1).

Furthermore, results revealed an effect of cluster on each internal load measure ($P < .001$), with post hoc analysis showing lower values in C3 compared with C1 and C2 ($P < .05$, effect sizes range *small* to *moderate*; Figure 2).

Discussion

This is the first study to classify training sessions based on the external load experienced by volleyball players during the preseason period. The main results indicate that Jump and PL are the main external load measures classifying the workload completed during training sessions throughout the preseason period, highlighting the importance of monitoring these external load measures. Moreover, the analysis of internal load showed higher objective and subjective internal loads in sessions characterized by higher external loads compared with those with lower external loads, suggesting that adopting a monitoring system using a cluster analysis might be a valuable option to plan higher or lower internal responses of the athletes.

Our finding indicates that Jump is the main external load measure when training sessions are classified in low, moderate, and high loads with players completing 161 (36) Jumps (min: 33, max: 274) in C1, 98 (33) (min: 25, max: 179) in C2, and 63 (40) (min: 5, max: 165) in C3 per session. This is not surprising due to the volleyball intrinsic characteristics mostly encompassing vertical demands. To the best of our knowledge, only one previous investigation[21] has previously assessed the number of Jumps performed during the preseason period showing a lower Jump

Table 1 Players' External-Load Measures in High, Moderate, and Low Clusters, Mean (SD) [Minimum–Maximum]

External-load measure	Cluster 1—high load (n = 72, 30.1%)	Cluster 2—moderate load (n = 76, 31.8%)	Cluster 3—low load (n = 91, 38.1%)
Jumps, n	161 (36) [33–274]	98 (33) [25–179]	63 (40) [5–165]
Player load, AU	547 (73) [409–738]	489 (61) [369–680]	401 (71) [240–579]
Changes of direction, n	463 (130) [231–792]	462 (96) [305–697]	293 (87) [110–489]
Accelerations, n	144 (43) [59–359]	156 (37) [79–248]	96 (28) [30–201]
Decelerations, n	180 (42) [111–383]	124 (28) [60–210]	111 (51) [23–263]

Abbreviation: AU, arbitrary unit.

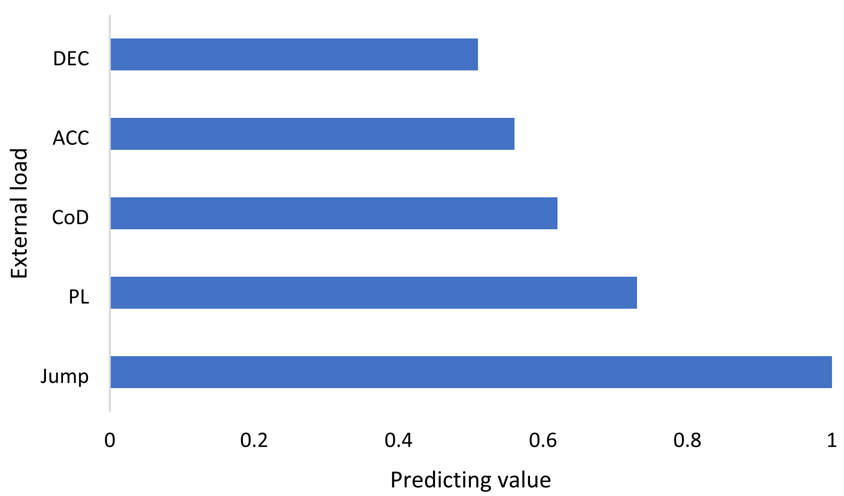

Figure 1 — Players' predictor importance on external-load variables. ACC indicates acceleration; CoD, change of direction; DEC, deceleration; PL, player load.

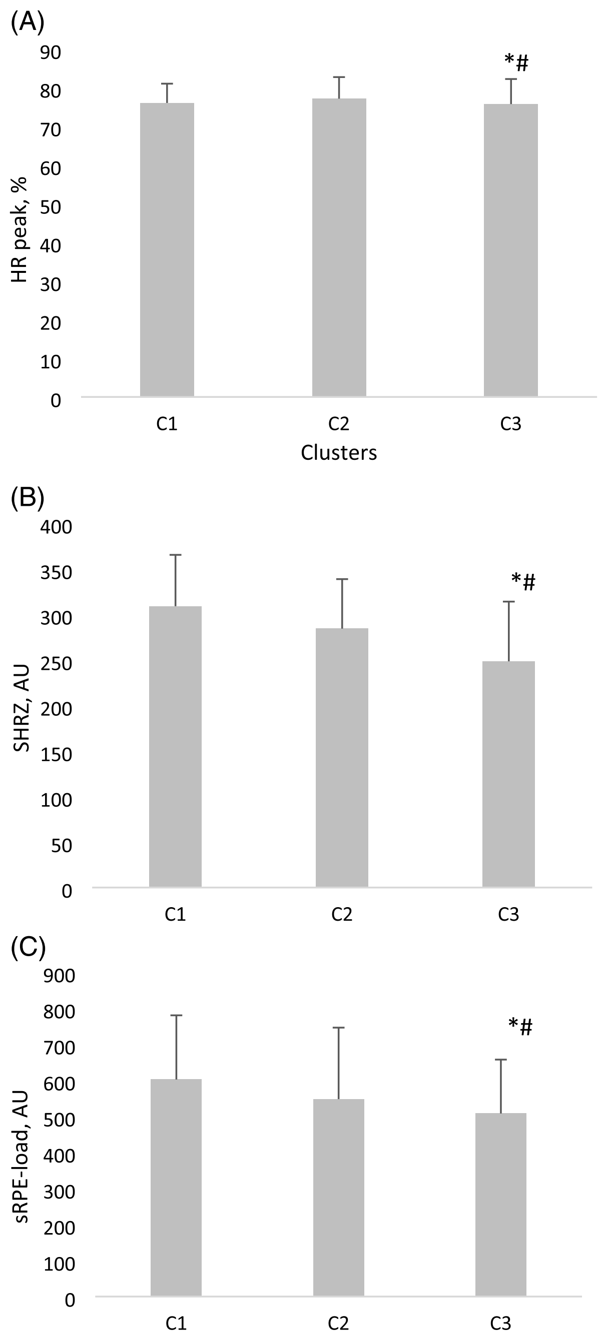

Figure 2 — Differences between clusters in (A) %HRpeak, (B) SHRZ, and (C) sRPE-load. C1 indicates cluster 1 (high); C2, cluster 2 (moderate); C3, cluster 3 (low); ES, effect size; %HRpeak, percentage of peak heart rate; SHRZ, summated heart-rate zones; sRPE, session rating of perceived exertion. *Significant differences compared with C1 (%HRpeak: $P < .001$; ES = 0.60; [0.28; 0.91], moderate; SHRZ: $P < .001$, ES = 1.16 [0.83; 1.49], moderate; sRPE: $P = .001$, ES = 0.57 [0.26; 0.89], small). #Significant differences compared with C2 (%HRpeak: $P < .001$, ES = 0.65 [0.34; 0.96], moderate; SHRZ: $P < .001$, ES = 1.03 [0.71; 1.36], moderate; sRPEload: $P = .016$, ES = 0.44 [0.13; 0.74], small).

load compared with our findings in male volleyball players competing in the top-2 Dutch volleyball leagues. Indeed, an average of 270 Jumps per week over an average of 6 weekly training sessions, corresponding to ~45 Jumps per training session was reported, which fit within our low-load cluster (C3). A possible reason for this discrepancy might be the different methods used to record the number of Jumps including the use of IMU from different brands (T6 devices from the Catapult company vs Zephyr Bioharness device from the Zephyr Technology company and video analysis techniques). Other studies[22,23] assessing the number of Jumps in male volleyball players during training sessions also showed lower number of Jumps compared with our results, but they were focusing on the assessment of the jumping load throughout the full season, not differentiating between pre- and in-season periods, making any possible comparisons difficult to make. Overall, to the best of our knowledge, this is the first study providing detailed information about the jumping load of male volleyball players during the preseason period and classifying training sessions applying a cluster analysis technique. These outcomes can provide interesting insights for volleyball coaches, indicating the number of Jumps that a team should complete to classify their session as high, moderate, or low during the preseason period. Providing these benchmarks could provide essential information for volleyball coaches and practitioners when planning and monitoring their training sessions during the preseason period.

While monitoring the movement performed by volleyball players on the sagittal plane is fundamental since Jump represents the main action performed during training session and matches it should be considered that this approach might underestimate the movements performed on other axes particularly for liberos. In fact, in addition to jumping, to have a more holistic approach, the analysis of other movements performed on other planes has been considered fundamental in defining the external load of volleyball players.[24] In line with this idea, we tried to define the other external training load measures able to classify training sessions based on the load carried out, showing PL as better cluster predictor compared with CoD, ACC, and DEC. A possible reason for our finding is that PL is more appropriate in capturing the multidirectional nature of volleyball since, different from CoD, ACC, and DEC, it considers the movement performed on the 3 planes, including the sagittal plane (main movement in volleyball). Overall, PL might be considered as a comprehensive measure of the external load to be monitored by volleyball coaches and practitioners during training sessions.

In previous studies using clustering technique to classify the load of players during training and games, an approach including external or internal loads only was used. For instance, in a recent study,[11] various external load measures recorded via ultra-wide band and IMU technologies during official first division Spanish basketball matches were clustered to categorize zone intensities across various playing position. Differently, a cluster technique was adopted by Rabelo et al[3] to classify the training sessions based on player's internal load (ie, rating of perceived exertion) across a full season in a professional futsal team, with 3 clusters identified during the preseason period (low load = 2.9 [0.5] AU, moderate load = 4.7 [0.6] AU, and high load = 6.0 [0.9] AU). Nevertheless, an analysis of clusters taking into consideration both the internal and external load might provide a more holistic monitoring approach for team sport coaches. Indeed, while monitoring external load is fundamental to assess the load performed during volleyball training sessions, monitoring internal loads is also important to provide an idea about the responses occurring during the training sessions and the overall possible adaptations occurring throughout the preseason period. This is particularly relevant in volleyball considering previous studies indicated the need for a monitoring process including both internal and external load measures due to their low commonality.[25] To the best of our knowledge, this is the first study assessing the differences occurring in internal load measures between sessions classified by their external load indicating a statistically lower objective and subjective internal loads in the sessions characterized by the lowest external load compared with the moderate- and high-load clusters. Differently, no differences were evident between the moderate- and high-load clusters. These results are partially in line with our expectations since a difference across all clusters was expected. Indeed, higher internal responses were expected during sessions with higher external loads, although they can be mediated by various factors (fitness levels, fatigue, etc).[4,26] Unfortunately, we were not controlling possible influencing variables in our analyses, but it may be interesting for our results to be interpreted by volleyball coaches, and practitioners since they can provide some comparative data to be used when monitoring loads in male volleyball players during the preseason period.

While our study provides interesting scientific and practical insights for volleyball coaches and practitioners, some limitations should be acknowledged. Indeed, our study only focused on the preseason period, while a more comprehensive analysis of the other parts of the seasons (in-, post-, and off-season) is warranted. Moreover, our analysis clustered players together, while a longitudinal analysis of the individual players' external load, and corresponding elicited internal load including an analysis considering the court playing positions might provide more detailed results for the coaching staff. Therefore, future studies should focus on applying a similar approach to this investigation including other periods of the volleyball season and providing additional individual analyses.

Practical Applications

The outcomes of this study have various practical implications for volleyball coaches and practitioners. Specifically, our study proposes the adoption of an additional monitoring approach including cluster analysis to classify the training sessions based on the external load performed during the preseason period. Indeed, together with a load monitoring approach focusing on the daily, weekly, and monthly analysis of the load performed by players, our approach can provide useful feedback for coaches to understand which performed session can be considered with high, moderate, or low loads, providing benchmarking values to be used when planning the load for the upcoming sessions and parts of the seasons. For instance, a session that was planned to be with high load might not be considered so if not reaching a certain threshold value, which can be provided thanks to our load clustering approach. As a practical example, based on our results, a session including ~160 jumps per sessions and ~550 AU of PL can be considered with a high volume and is likely to elicit an internal load statistically higher than sessions including ~60 jumps and ~400 AU of PL, which can be considered as low-load sessions. In practically applying and interpreting these values, they should be contextualized by the level of competition, the number of weekly training sessions, the fatigue status of players, and the coaching philosophy adopted by the coaching staff.

Based on our outcomes, it is also suggested that, when not possible to monitor other external load indicators, coaches should mainly focus on jumps, and PL, which are the main variables classifying the clusters, including not only movements performed on sagittal plane (ie, Jump), but also on the other planes (ie, PL). Finally, our findings provide reference values about the internal load elicited by the high-, moderate-, and low-load sessions with %HRpeak, SHRZ, and sRPE-load. Specifically, high-load sessions are characterized by ~75.5% of HRpeak, ~309 AU of SHRZ, and ~600 AU of sRPE-load, while low-load sessions encompass % HRpeak of ~76%, SHRZ of ~250 AU, and sRPE-load of ~500 AU.

Conclusions

Our results provide information about the external load registered in male volleyball players during the preseason period for sessions including high, moderate, and low load. Moreover, jump and player load can be considered the main external-load measures to be monitored during the preseason period in male volleyball players. Finally, the classification of the external-load measures in high-, moderate-, and low-load sessions had an influence on the internal-load measures with a lower percentage of peak heart rate, summated heart-rate zones, and session rating of perceived exertion load in the low-load cluster (C3) compared with high- and moderate-load clusters. Collectively, these results could help male volleyball coaches in the monitoring process of the preseason period sessions, providing benchmarking values of external- and internal-load values across high-, moderate-, and low-load sessions.

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