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Automated IMU-based training load monitoring in beach volleyball

Strotkötter, C.1, Groh, B.2, Prabhakar Rao, A.1, Kaartinen, N.3, Kern, A.3, Pfeiffer, M.1

1. Johannes Gutenberg University Mainz, 2. Ben's Consulting & Data Analytics, 3. Kaasa solution GmbH

INTRODUCTION:
Optimizing training load management is of great importance in beach volleyball to elicit elite performance and avoid injuries. Due to the sandy ground surface and the structure of the game (3-contact rule, two persons per team), in addition to jumps, it is primarily short sprints, fast lateral movements, and dig movements with direct follow-up action that determine the degree of stress and load on the players [1]. Therefore, we developed a practical and cost-effective monitoring approach to automatically identify and quantify relevant events and ultimately enable an informed training load and recovery management.
METHODS:
The developed system consists of an IMU-based event detection (ED) as well as action classification (AC). Kaasa Data Collector application was used to collect raw data from standardized training sessions (n=7, male German national level) using six channels of data (3D accelerometer + 3D gyroscope) from three synchronized sensors (Movesense IMU, left/right upper arm and chest strap, 104Hz each). Basic techniques (set, pass, service), jumps (jump service, attack, block) and defensive actions (defense, digs, sprints) were tagged in real time with hot buttons and reviewed by video.
ED: two-stage sliding window approach (0.5 sec); stage I: suprathreshold L2-normalized values of accelerations and angular velocities of the sensor on the hitting arm (right arm); stage II: suprathreshold upward rotations of the hitting arm and supporting arm.
AC: classification of eight specific actions (serves with and w/o jumping, reception, defense/digs, sets, attacks, and blocks with and w/o preliminary movement) using data of -1.5/+0.5 sec around automatically detected events. (a) Normalized feature vectors (statistical: min, max, mean, etc., specific: rotation during the event, etc.) were classified with Naive Bayes, kNN and C4.5 Decision Tree; CV / LOSO-CV was performed by open-source software ECST [2]. (b) raw data was classified using a sequential neural network model (Tensor flow light, 70% training, 15% test, 15% validation).
RESULTS:
ED: 1481 automatically detected events (1040 TP / 441 FP; 1346 manually annotated actions); recall: 77.3% (306 FN) and precision: 70.2%; AC: accuracy (a) 75.4% to 94.7% and (b) 90.1%.
CONCLUSION:
Traditional classification approaches as well as machine learning methods were used successfully to automatically detect and classify beach volleyball specific movements. Machine learning appears to be superior compared to traditional approaches. However, recall and precision of ED as well as accuracy of AC still need to be improved further to effectively support training load management and recovery of athletes.
1: Pelzer et al. (2020). Int J of Sport Science & Coaching, 15(5-6), 717–727.
2: Ring, M. et al. (2012). IEEE, Proceedings 2012 21st ICPR.

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