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LOADS ACTING ON THE LOCOMOTIVE SYSTEM OF PROFESSIONAL FEMALE VOLLEYBALL PLAYERS DURING THE LANDING PHASE OF SPIKES AND BLOCKS

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The purpose of this study was to identify force and time characteristics of ground reaction forces produced during the landing phase of volleyball technical elements: blocks and spikes. Applying piezoelectric dynamometry and video recording, a series of tests were carried out with the participation of four female volleyball players of the first team of AZS AWF sports club competing in the Female Volleyball League. The recorded force vs time line graphs of ground reaction $R_x(t)$, $R_y(t)$ and $R_z(t)$ were used to calculate the values of kinematic-dynamic parameters that describe the level of dynamic loads. Results show that the majority of loads in these movement tasks is significant and may be traumatogenic.

KEY WORDS: reaction forces, piezoelectric platform, traumatogenicity, volleyball.

INTRODUCTION: Jumps in such volleyball technical elements as spikes and blocks, executed repeatedly by players during volleyball matches result in serious exploitation of the locomotive apparatus. According to Goodwin-Gerberich (1987) 63% of musculoskeletal system injuries in volleyball players occur as a result of take-offs and landings in such fundamental volleyball elements as blocks and spikes. In the process of transmission of the loads accumulated, as a result of performing volleyball techniques by the locomotive system, the strength of the tissues may be exceeded. Pathological results of locomotive system overloads in female volleyball players are injuries of the musculo-articular apparatus of the lower limbs, particularly in the region of ankle and knee joints, with the frequently occurring problem - the ACL injury (Ferretti, 1992). Particularly common traumatogenicity of the knee joint can be observed in female volleyball (Brinner and Kacmar, 1997). Ferretti (1992) reported that ACL injuries of female volleyball players occur two to eight times more frequently than for male volleyball players. Female volleyball players are characterized by different lower limb biomechanics than male volleyball players, which is determined by dissimilar build of the pelvis, expressed in form of kinematic-dynamic parameters (Salci et al., 2004). Significant loads acting on the players' locomotive system during landings that follow spikes and blocks are indicated by high maximum values of the vertical component of ground reaction force (more than 5 BW for the attack line spike). These loads were recorded during a pilot study preceding this research, conducted with participation of two professional female volleyball players (Dworak and Kabacinski, 2006).
The purpose of that study was to identify force vs time characteristics of ground reaction forces recorded during landings that followed typical volleyball technical elements - blocks and spikes, in order to determine the scale of dynamic loads acting on the locomotive system of female volleyball players of the AZS AWF sports club.

METHODS: Biomechanical tests were carried out on four female volleyball players representing AZS AWF Poznan sports club in the highest Polish competition category – the Female Volleyball League (season 2007/2008) - aged (25.7±6.4) years and possessing (13.3±6.0) years of competitive experience. The body weight and height of the players were 74.9±7.3 kg and 182.6±6.7 cm, repectively. *BMI* reached the level of 22.5±1.7 kg/m^2, whereas the Rohrer's index *RI* was equal to 1.2±0.1 g/cm^3.
The measurements were carried out in the biomechanical-kinesiological laboratory of the Department of Biomechanics at University School of Physical Education (USPE) in Poznan, which possesses the ISO 9001:2008 Quality Management System certificate. The measurement system consisted of the following devices: piezoelectric KISTLER platform

type 9261A (1000 Hz sampling frequency), charge amplifier type 5001, 16-channel 12-bit A/D converter (AMBEX) linked with the platform, a personal computer with software and two digital CANON cameras (25 Hz recording frequency) placed in one lateral plane at the height of 50 and 220 cm. A 2 cm thick wooden board covered with a layer of fitted carpet glued onto its surface was attached to the external part of the platform. In order to recreate real conditions, a net was hung in the laboratory at the prescribed height of 224 cm (fig.1). The values of the kinematic-dynamic parameters could be established on the basis of line graphs of ground reaction force components $R_x(t)$, $R_y(t)$ and $R_z(t)$, recorded during the take-off and landing phases of typical volleyball movements thanks to the use of a special computer program, produced at the Department of Biomechanics of USPS in Poznan by one of the coauthors of this study.

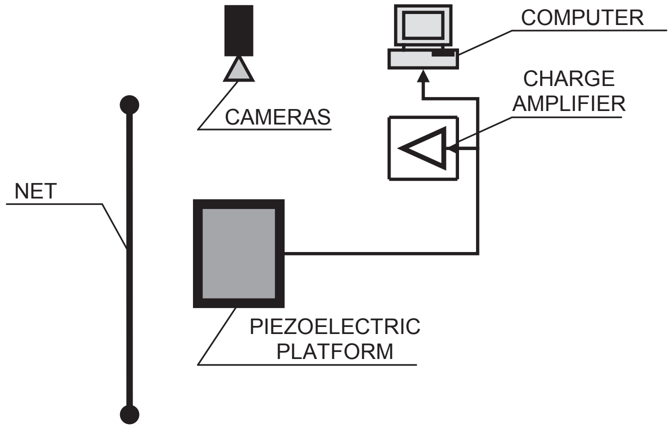

Figure 1: Diagram of the measurement system

The female volleyball players performed the following technical elements: block from a run-up, attack line spike, back row attack spike, slide attack spike. From several repetitions of the above mentioned volleyball actions, the authors selected three attempts that were (on the basis of video screening) technically comparable for each player.
The recorded force vs time line graphs of the vertical component of ground reaction force *Rz(t)* during landing were used to determine the following kinematic-dynamic parameters:

- tlz_{max} – time to maximum force Rzl_{max},
- Rzl_{max} – maximum value of the vertical component of ground reaction force,
- $<Rzl>$ – mean (integral) value of the vertical component of ground reaction force (1)
- Izl – buildup index of the vertical component of ground reaction force (2)

$$< Rzl >= \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} Rzl(t)dt \ , (1) \qquad Izl = \frac{Rzl_{max}}{tzl_{max}} \ (2).$$

The results were submitted to statistical analysis with the use of the STATISTICA 8.0 program. The authors calculated the arithmetic averages (*AV*) and standard deviations (*SD*) of age, somatic parameters as well as times, ground reaction forces and force buildup indexes. The Shapiro–Wilk test was used to assess the conformity of the statistical distributions of the analyzed variables with a normal distribution. The significance of differences between the mean values of analyzed kinematic-dynamic parameters: times, ground reaction forces and force buildup indexes in particular volleyball actions were verified with the use of a nonparametric Friedman ANOVA test at a level of $p<0.05$.

RESULTS: Figure 2 presents an example of the force vs time line graphs regarding the vertical component of ground reaction *Rzl(t)* during landings that followed four technical elements performed by the female volleyball player that obtained the highest values of force Rzl_{max}.

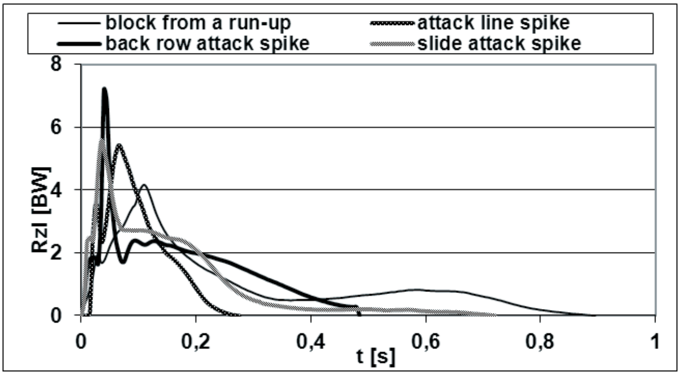

Figure 2: Line graphs of the vertical component of ground reaction force during landing

The values of physical parameters calculated on the basis of line graphs of *Rzl(t)* during the landing phase in typical technical elements performed by the female volleyball players - blocks and spikes - are presented in table 1.

Table 1
Values of kinematic-dynamic parameters calculated on the basis of the *Rzl(t)* line graphs

Landing	tlz_{max} [s]	Rzl_{max} [BW]	<Rzl> [BW]	Izl [BW/s]
1. Block from a run-up	0.09^F±0.02	3.88^F±0.25	1.57±0.11	44.57^F±11.85
2. Slide attack spike	0.06^F±0.01	5.48^F±0.16	1.48±0.28	103.34^F±24.41
3. Attack line spike	0.06^F±0.01	5.35^F±0.32	1.62±0.36	89.20^F±15.19
4. Back row attack spike	0.05^F±0.01	6.87^F±0.37	1.73±0.09	143.90^F±22.41

^{F}- represents statistical significance at the level of $p<0.05$ in the Friedman ANOVA test

Applying the nonparametric Friedman ANOVA test, at the level of $p<0.05$ statistical significance of differences between mean values of the following analyzed parameters was observed: time to maximum value of the vertical component of ground reaction force (tlz_{max}), maximum values of the vertical component of ground reaction force (Rzl_{max}) and force buildup index (*Izl*) during the landing phase of particular technical actions of female volleyball.
The shortest time tlz_{max} was observed for landings that followed a back row attack spike (0.05±0.01s). This value was significantly lower - by 16.7% and 44.4% respectively - in relation to times tlz_{max} recorded during slide attack spikes and attack line spikes as well as blocks from a run-up. Values for Rzl_{max} of 6.87±0.46 BW, which occurred during landing after a back row attack spike were significantly 20.2% higher in relation to the value of this parameter for the slide attack spike attack line spike (by 22.1%) and block from a run-up (by 43.5%). The highest value of force buildup index *Izl* was recorded in the landing phase that followed the back row attack spike (143.90±28.06 BW/s). It was statistically higher by 28.2%, 38.0% and 69.0% compared with the slide attack spike, the attack line spike and block from a run-up, repectively. No statistically significant differences in integral mean values of the vertical component of ground reaction force were observed in the above volleyball elements during the landing phase (on the basis of the ANOVA Friedman test, $p<0.05$).

DISCUSSION: Extreme values of the vertical component of ground reaction force during landings occur soon after impact. Short-lasting movements of lower limb segments during

the landing phase that follows volleyball jumps aimed at spiking and blocking are controlled in the open loop of the neuromuscular process. In the Bernstein motion control model (Morecki et al., 1971, Nigg and Herzog, 1999) the time of complete circulation of information from the program to the controlling mechanism by amplification – from the spinal cord to the muscles - exceeds the values of time ranges of duration of these phases in the analyzed movements. Such an exceptionally short time of generation of impact forces, renders as impossible the introduction of correction signals into the random movement control loop.
Generation of the highest values of ground reaction forces during landing after a back row attack spike is caused by the fact that in this technical element the locomotive system of the female volleyball players during the take-off phase is characterized by the highest values of take-off dynamics parameters and height of elevation of the general mass center during the flight phase. The technical correctness of this movement technique during the volleyball match is in its principle aimed at performing the jump with optimal values of these kinematic-dynamic parameters in order to dynamically spike the ball above the opponent's block.
Short times of tlz_{max} and high values of Rzl_{max}, which exceed several times the body weight (*BW*), produce high values of force buildup indexes *Izl*, which exceed the 100 BW/s value during landings after spikes. This indicates the existence of significant loads acting on the locomotive apparatus of the players during the so called impact phase of the landing, during the eccentric work of the muscles responsible for extending joints of the lower limbs during movements specific to volleyball players.

CONCLUSION: This study has demonstrated that the impact phase of blocks and spikes produces relatively high peak and average values of ground reaction forces and force buildup indexes. Forces that put the highest strain on the locomotive system were generated during the landing phase that followed a back row attack spike. Accumulation of these loads, caused by repeated performance of jumps during the entire sports career of volleyball players, may in the end result in exceeding the strength of muscle, bone and ligament tissues. That is why the loads acting on the locomotive apparatus of female volleyball players during the landing phase of blocks and spikes constitute a serious traumatogenic factor.

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