FOOT-MOVEMENT, LOAD AND INJURY IN VOLLEYBALL

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Many human movements are very typical to one sporting activity. Such movements may be a particular way of hitting a ball (whole body movement) or placing the foot on the ground (one segment movement). Movements are the result of acting forces and as a consequence lead to a loading of joints, tendons and other anatomical structures. Load on the other hand is recognized as a critical factor regarding the occurence of pain and injury (Nigg, Stuessi). So movement, load and injury are related to each other. In running this relation has been pursued for a number of years, in other sports, i.e. volleyball it is almost unknown.

The goal of this presentation is twofold: (1) To present a structuring of the game of volleyball in order (2) to establish a relationship between foot-movement, injury and load. Applications are presented using selected examples.

METHOD

Three separate investigations were undertaken with different methodological procedures. Whole body movements of a volleyball player are referred to as "moves", one segment movements of the foot are referred to as "foot-movements".

Procedure 1: Structuring The Game

Eleven well known volleyball moves such as covering or blocking were counted out on a middle class women volleyball team (n=6) using a video system. Each individual player was observed over a total of 20 minutes which added up to more than 1200 observations for the whole team. The average frequency distribution for these moves was then calculated for one game-hour taking in account the different volleyball positions like setter, hitter and allrounder. These moves were then subdivided into ten groups of foot-movements such as placing the foot sideways, jumping and landing. The distribution of foot-movements based on another 400 observations. This lead to an average distribution of ten defined foot-movements within eleven defined volleyball moves calculated for one game-hour. These results were then checked on players of international level.

Procedure 2: Foot-movement, Injury and Pain

Information on how injuries and pain occurred on the lower extremities and back was needed. For this, 36 nationally ranked volleyball players were asked to fill out a detailed questionnaire. Injury was defined as a suddenly occuring event which forces the athlete to stop his work-out and competition for several weeks. Pain was defined as a slowly developing health problem which forces the athlete to adapt his moves during work-out and competition, including a possible short break for a few days. Filling out the questionnaire, none of the volleyball players did have any difficulties to relate his health problems to these two categories. In addition to pain and injury, the athletes had to state their observations in regards to volleyball shoes and volleyball courts.

Procedure 3: Load

Based on the first two investigations jumps and landings were recognized a crucial part of the game with respect to occurring health problems. For this reason the block was chosen as one typical volleyball move to establish the order of magnitude of acting impact forces. A force platform was placed close to the net such that the volleyball players landed with one foot on it after blocking a spike. This game-like situation was repeated ten times by a total of twelve players. In addition, one subject performed 10 trials each with two different pairs of shoes.

RESULTS AND DISCUSSION

Structuring The Game

The most often occurring moves in volleyball are those without the ball, the position switches after a service or the moves towards the ball. The second most moves are those where the volleyball players run to support or cover an action of a teammate. Only then, all the moves with the ball occur, like the block, reception and so on, but considerably less than the moves without the ball. This was the case for all players of the team. Specialization was evident (hitter, setter), but basically did not change the distribution of volleyball movements (Figure 1a,b,c).

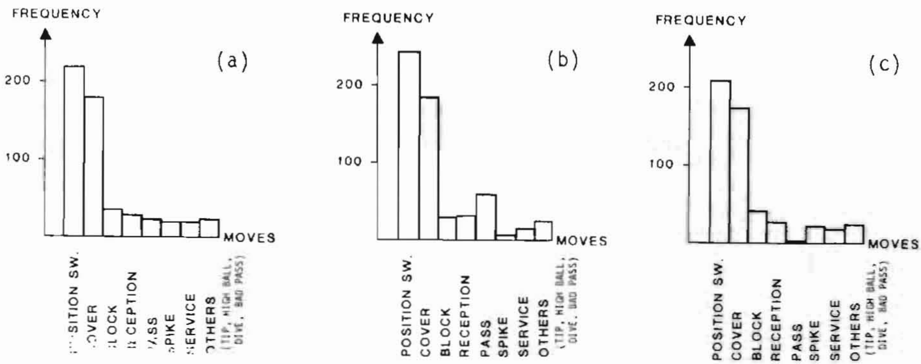

Figure 1. Average distribution of volleyball moves, (a) allrounder , (b) setter and (c) hitter, calculated for one game-hour.

Each of these moves were then analyzed and classified into different foot-movements (Figure 2). It is evident that running foot-movements in different directions are dominant in the game of volleyball. All other foot-movements are related to jumps and landings. These added up to about 100 each for each player for one game-hour and are mainly found in blocks and spikes. The "high intensity" jumps and landings are almost exclusively noted at the net, the "low intensity" jumps and landings when performing a pass or a serve. In addition, jumps and landings on one foot were also observed. These added up to another 30 for each player for one game-hour. Particularly landings on one foot can be considered as risky in respect to possible injuries. On the other hand it is interesting to note that rotations of the foot -- visible on the video screen -- did hardly occur at all.

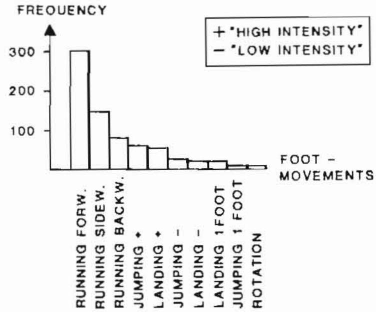

Figure 2. Average distribution of foot-movements in volleyball calculated for one game-hour.

Foot-movement, Injury and Pain

The foot-movements were then looked at in respect to the frequency of injury and pain summarized from the questionnaires. Injuries at the lower extremity and back were almost exclusively found on the foot (Figure 3a), often in combination with an "unhappy" landing on another player's foot and in a few cases in a forward move. Most of these injuries were sprained ankles. It should be mentioned here that being airborne the relaxed foot tends to rotate into supination which is recognized as the most unstable position of the ankle (Stuessi). In other words, lower extremity injury in volleyball seems to occur most often either with a relaxed supinated foot position at touch down or with an "unhappy" landing. Other injuries on the lower extremity and back were hardly found at all.

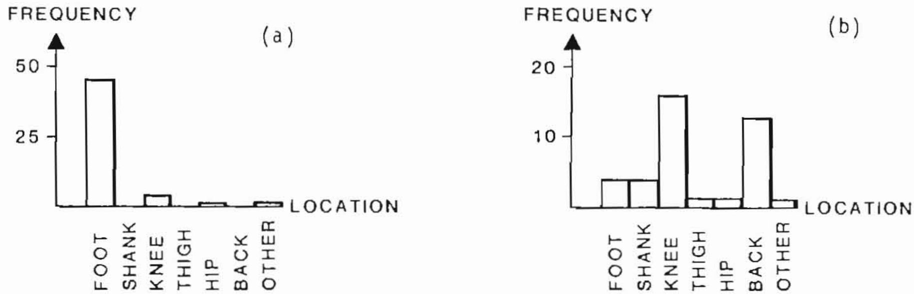

Figure 3. Distribution of volleyball (a) injuries (n=52) and (b) pain (n=40) on the lower extremities and back

The distribution of pain was found different to that of the injuries. Here the problems at the knee and back were found dominant (Figure 3b). The related literature shows (Steinbrueck, Widera), that these figures correspond well considering that the distinction between pain and injury is not used very often. From the questionnaire it was evident that the volleyball players related their pain to the jumps and landings and to the high intensity of training. So the most sensitive joints in respect to high incidence of loading are the knee and spinal column at the lumbar region.

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Load

Impact forces in landing range from 1000 to 2000 N under the forefoot and from 1000 to 6500 N under the heel which is of the same magnitude as previously reported (Nigg, Valiant) for other landing experiments. The large range of force values indicates, that the impact forces in landing are influenced by different factors such as jumping height, landing technique, body mass, shoes and the surface of the volleyball court. In the view of a volleyball player the most practical ones to be changed are the landing technique and the shoes.

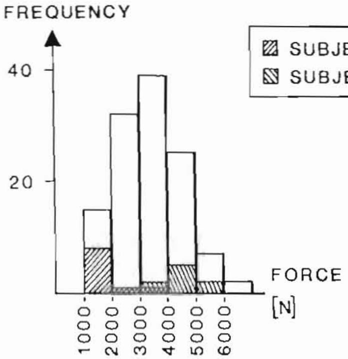

Figure 4. Distribution of impact forces in landing after a block (n=12, 10 rep.)

The critical limits for cartilage were determined by Yamada (1970) to 500 N/cm2 for the change from elastic to nonelastic and 1000 N/cm2 for ultimate stress. When trying to apply this to the knee two factors have to be considered: The effective mass and the non-planar surface at the knee (Denoth, 1986); the surface area at the knee joint may be approximated to 10 cm2. Taking this into account the elastic limit of the cartilage is achieved at about 5000 N. In this experiment 8 out of 120 landings were over this critical value which indicates that high loads at the knee joint are not a rare incidence. This may be a further explanation why knee problems are found often among volleyball players.

The load at the knee joint can be reduced by moving into a crouched position after the landing which is hardly applicable in playing volleyball. On the other hand an increased use of the calf muscles during landing can slow down the impact of the heel on the ground and so reduce impact loading. This was performed by a number of subjects in this study, but not consistently.

The shoes can also help to reduce impact forces at touch down from a block. The difference can be up to 30% when changing from a thin soled shoe to a thick soled shoe (Figure 5). Note that both of these types of shoes are used regularly on volleyball courts. Since volleyballers like to be close to the ground they often prefer thin soled shoes which are considerably worse for the impact situations in respect to pain at the knee and back. However, thin soled shoes have a very small leverage between the ankle joints and the ground which is of advantage if a lack of ankle stability is the main health problem. So, if injury or pain are apparent, both types of shoes can be used but should be chosen selectively.

Additionly the properties of the court surface can also add to reduce impact load. It seems interesting to note that in this study in the opinion of the volleyballers the courts tend to be too hard rather then too soft, a further point which accounts for the health problems stated above.

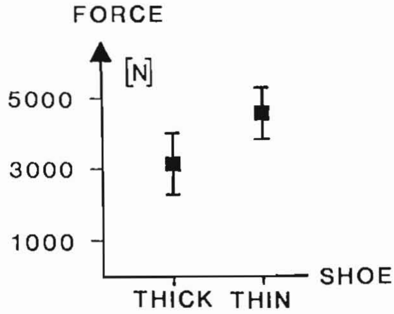

Figure 5. Comparison of impact forces with two different shoes (1 subj., 10 rep., mean, sd)

CONCLUSIONS and APPLICATIONS

There are a number of applications which follow from the results stated above. Both pain and injury seem to originate from the same move, the jumps and landings. In one case (injury) it has to do with a single event or accident situation, in the other (pain) with many repetitions of the same type of loading. For the prevention of injuries at the ankle an increased ankle stability is of advantage. This may be achieved by:

- Training of peroneus muscles.
- Use of external help (tapes, high shoes, ankle braces).
- Use of thin soled shoes.

For the problem of pain there are more long term effects which have to be considered:

- Training of calf muscles to reduce impact load at landing.
- Use of thick soled shoes.

These conclusions show that both the shoe and the athlete can contribute to prevent health problems. So, volleyball players and coaches should not only consider the right choice of shoes but should also reflect on an adequate training which can considerably help to reduce the risk of injury and pain.

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