INTRODUCTION
Highly ranked youth badminton players seem to have a different stroke technique compared to lower ranked players. However, it can be difficult to discover the exact difference in the execution when observing them in a training session. In the present study the aim is to examine the proximal-distal sequence in clear strokes performed by youth players of different skill levels. This well-known whiplash type of motion has attracted the attention of several scientists and is associated with skilled movements [1].

The overhead forehand and backhand clear strokes were subject to the analysis. These strokes provide the basis of playing the shuttle from the player’s own backline to the opponent’s backline and are among the most common and important of all badminton strokes. The purposes of the strokes are similar, yet the execution seems quite different. In particular, less skilled players seem to have trouble creating adequate speed of the racket head, when they perform a backhand clear stroke.

The purpose of the present study was to investigate biomechanical differences in stroke technique of the forehead clear and backhand clear between youth badminton players of different skill levels. We will examine the proximal-distal sequence in relation to the energy transfer between segments caused by joint reaction forces hypothesizing that this energy transfer has to be optimized in order to produce a good clear stroke.

METHODS
A total of 20 male subjects, aged between 13 and 14, were chosen for the study; 10 subjects were skilled players (group A) and 10 subjects were less skilled players (group B). Their skills were reflected in a Danish ranking system: Elite (E), Master (M), A, B and C. All subjects in group A had the ranking E or M, whereas the subjects in group B had the ranking B or C.

Reflective spherical markers were attached at landmarks on the subject’s body. In addition five markers were attached to the racket. The motion capture data was recorded using a Qualisys Oqus 300 system (Gothenburg, Sweden) which consisted of eight high-speed cameras sampling at a maximum frame rate of 500 Hz. The high frame rate was necessary to capture the majority of the high-speed racket movement. For each subject 10 successful forehand and 10 successful backhand clear strokes were recorded.

The data analysis was mainly carried out using the The AnyBody Modeling System 4.2.1 (AnyBody Technology A/S, Aalborg, Denmark), where the data was imported through a zero-phase, fourth order Butterworth filter with a cutoff frequency of 20 Hz. The system allows both a kinematic and kinetic analysis of the movement [2]. The multi-segment model consisted of the thorax, the upper limb and a racket, as shown in Figure 1.

![Figure 1: The skeletal model in The AnyBody Modeling System.](image)

Power is transferred over joints by joint torques and by joint reaction forces. The power caused by joint reaction forces ($P_r$), can be calculated as the scalar product:

$$P_r = F \cdot v,$$

where the three-dimensional vectors $F$ is the joint reaction force and $v$ is the linear velocity of the joint center.

Calculating the net change of energy in the segments, due to joint reaction forces, makes it possible to determine to which extent, the subjects are able to transfer energy from proximal to distal segments. Let $P_{r,el}$, $P_{r,wr}$ and $P_{r,hr}$ denote the joint powers of the joint forces at the elbow, wrist and hand-racket joint, respectively. Then the net change of energy of the forearm ($E_f$), in the period from $t_1$ to $t_2$, due to joint reaction forces is:

$$E_f = \int_{t_1}^{t_2} P_{r,el}dt - \int_{t_1}^{t_2} P_{r,wr}dt.$$
Similar computations are valid for the two remaining segments. To calculate the net change of segment energy, numerical integration was applied, using the trapezoidal rule.

RESULTS AND DISCUSSION

The forehand clear stroke
With regards to the joint power produced by joint reaction forces, the time-power graphs of the four joints followed the same pattern for all subjects. The time-power graphs showed a proximal-distal sequence where the joint powers attained peak values in the following order: Glenohumeral, elbow, wrist and hand-racket joint. Hence, no significant differences were found between the two groups, as illustrated on Figure 2.

Figure 2: The time occurrence of the maximal glenohumeral (GH), elbow (EL), wrist (WR) and hand-racket (HR) joint power, from joint forces, averaged over all subjects in the two groups for the forehand clear stroke.

As it follows from Table 1 no significant differences in peak segment energies, due to joint reaction forces, were found in the forehand clear stroke.

The backhand clear stroke
Regarding the backhand clear stroke distinct differences were found between the two groups. With regards to the time-power graphs, all the skilled players showed a proximal-distal coordination (Figure 3), while most subjects within group B differed from this sequence in some way.

Some subjects showed a simultaneous timing of the glenohumeral and elbow joint power, while others showed a distal-proximal sequence. Furthermore, most subjects from group B showed a distal-proximal sequence with respect to the wrist and hand-racket joint. These deviations are illustrated in Figure 3.

Table 1 shows that the peak segment energy in the forearm and hand were significantly higher for the skilled players. Especially the tremendous difference found in the forearm should be noticed. Mean values of 18.35 ± 7.80 J for group A, and 6.49 ± 4.85 J for group B, were obtained in this case (p = 0.0004).

Hence, these findings may be the main reason for the slightly higher racket head velocity found in group A.

CONCLUSION
We conclude that the skilled players used a proximal-distal sequence, as regards to peak joint powers from joint reaction forces, in all strokes, thus transferring a considerable amount of energy to the distal segments. The less skilled players frequently deviated from this sequence, particularly in the backhand clear stroke. As a result, they did not transfer as much energy to the distal segments in the backhand clear stroke, as the skilled players did.

REFERENCES