# DIAGNOSIS AND ADVICE IN THE UNDULATING STROKES REQUIRES INFORMATION ON GLOBAL BODY FLEXIBILITY AND UPPER LIMB STRENGTH

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The locomotion and the physical characteristics of breaststroke and butterfly swimmers using the most undulating and the flattest variants will be compared. There is much more velocity variation of the centre of mass of the body in the flattest than in the most undulating variants. In the most undulating variants, during the largest part of the arm propulsion, a relatively small increase in velocity occurs. During the last part of the arm propulsion and the first part of the arm recovery, the velocity is relatively well maintained. During the first part of the bottomward leg kick, an early increase in velocity occurs. In butterfly higher flexibility scores correspond with more undulation. The individual undulation in butterfly is indicative for the best undulation in breaststroke. Flexibility and strength determine the best stroke and style variant per individual with a mean error in performance calculation of less than 3%.

**KEY WORDS**: undulating strokes, flexibility, strength

**INTRODUCTION:** Because most competitive swimmers do not find their best style on their own, since the seventies technique and dry land training advice were offered in a Research and Evaluation Centre in Leuven (Persyn et al 1982) (Figure 1). From the start of the diagnoses, it was assumed that in breaststroke and butterfly more flexible swimmers should undulate more, to obtain a more even velocity of the centre of mass of their body (CMbody), while more inflexible swimmers should use muscle strength of their upper limbs in flatter styles, despite more velocity variation of the CMbody. This assumption was confirmed by Van Tilborgh (1988), who calculated that the loss of energy, due to the large velocity variation of the CMbody in the flat breaststroke of the strongest swimmers, amounted to almost 25% of the total energy output.

(Poster Flander's Technology 1987)

A. DATA INPUT AND PROCESSING

1. An inquiry is filled in (from the logbook), containing: identification data; swimming performances for all strokes and distances; kicking and pulling performances; preferred stroke(s) and distance(s); training history: including the quantity and intensity of swimming and dryland training (flexibility, strength, endurance, ...).
2. Performance relevant physical characteristics (body structure and composition, flexibility and strength) are measured, using generally available or easily self-made instrumentation.
3. The inquiry and measurement information is entered and processed, providing individual profile outputs.
4. The movements are recorded with a rotating camera, simultaneously above and below the surface, using a periscope.
5. Because the images are extremely distorted, a manual video-digitizing system had to be developed to reconstruct the movement.

B. DIAGNOSIS AND ADVICE

6. The movement analysis allows detection of deviations.
7. For each poor flexibility or strength score, appropriate dryland exercises are proposed, along with advice on quantity and intensity of training. The progression in training and the evolution of scores are specified.
8. Before providing technique advice, the individual style is considered in relation to the physical characteristics, performance, sex, biological age and training history.
9. Based on the relevant physical characteristics, the best stroke and style variant can be calculated with a mean error in performance of 3%.

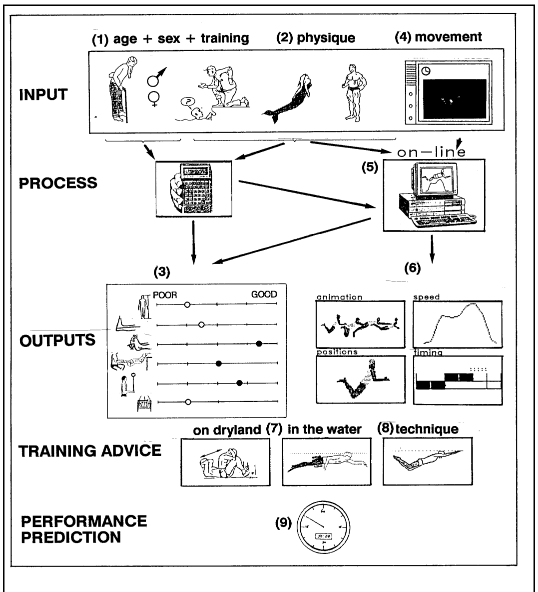



**Figure 1 - The kinesiological research and evaluation centre for diagnosis and advice.**

To answer the question presented at the previous ISBS congress 'What are the best breast-strokers doing now?' the movement analysis of 65 recent breaststrokers at international level was available (Persyn & Colman 1999). In addition, the physical characteristics and logbook data of 267 women and 307 men of at least national level were available. Because amplitudes of upper trunk rotation and of eel-like body waving (the so-called undulation) became progressively larger, hypotheses from dolphin and eel locomotion became more appropriate than from ship locomotion.
Because the butterfly influenced the breaststroke, in this paper, the locomotion and physical characteristics in the two strokes will be compared. Therefore, the movement analysis of 59 butterfly swimmers at international level was available.

**METHOD:** For diagnosis and advice, a sufficiently detailed but fast video-analysis was required. In breaststroke and butterfly, the diagnosis could start after about 30 minutes, by digitising only a limited number of specifically selected instants in one stroke cycle recorded from side view. 12 instants were selected in breaststroke and 18 in butterfly (delimiting phases of the leg kick, arm pull and recovery, as well as phases of trunk rotations and body waving). In Figure 2, the selected instants are presented in contour figures and compared to the stick figures, obtained after digitising and being used further in this study. For butterfly, the stroke cycle was defined by arm pull and leg kick phases separately.
The amplitude of undulation (defined by trunk rotations and body waving) was chosen as the criterion to distinguish individual styles. Therefore, measurements were made on seven of the 12 digitised instants in breaststroke and six of the 18 digitised instants in butterfly (Figure 2).
For body waving, angles in the shoulder, middle-trunk, hip and knee were measured. An S-shaped body position is the most typical instant (N=7 in breaststroke and N=13 in butterfly). In breaststroke, this instant is preceded by a dome-shaped body position (4) and followed by a cambered body position (10) (respectively a flexion and an extension of the whole body). For trunk rotation, the angle line hip-shoulder/horizontal was measured in various typical instants (Figure 2: breaststroke: 1, 2, 6, 7; butterfly: 8, 9, 12, 17). To be able to compare the amplitude of undulation between individuals, percentile scales were constructed from the (combination of) the angles measured on each of the typical instants.
The horizontal velocity variation of the centre of mass of the body (CMbody) was chosen as a criterion for effectiveness. To be able to compare balance mechanics and propulsion concepts in different style variant groups, composed by different age groups of women and men, the mean horizontal velocity of the CMbody per phase was expressed as a percent of the mean swimming velocity during the stroke cycle (Figure 3). This provided a satisfactory estimation of the acceleration and deceleration of the CMbody per phase.
To allow a kinesiological research and diagnosis, from the start of the Centre, characteristics of body structure and composition, joint flexibility and muscle strength were selected, inspired from careful observation of top level swimmers (Persyn, 1974). From the most relevant physical characteristics, profiles were constructed per stroke and later per style variant.
Further in this article, the locomotion and the physical characteristics of breaststroke and butterfly swimmers will be compared. Therefore, in each of the two strokes, a group of swimmers using the most undulating variants will be compared with a group of swimmers using the flattest variants (Figure 3). Because in the two strokes the most undulating styles were almost exclusively used by women, two groups of women were chosen (N = 5 in breaststroke, mean 100m time = 71.3s and N = 6 in butterfly, mean 100m time = 62.89s). Because the flattest styles were almost exclusively used by men, two groups of men were chosen (N = 5 in breaststroke, mean 100m time = 62.23s and N = 4 in butterfly, mean 100m time = 56.9s). It is evident that in these two strokes other variants exist between these two extremes.

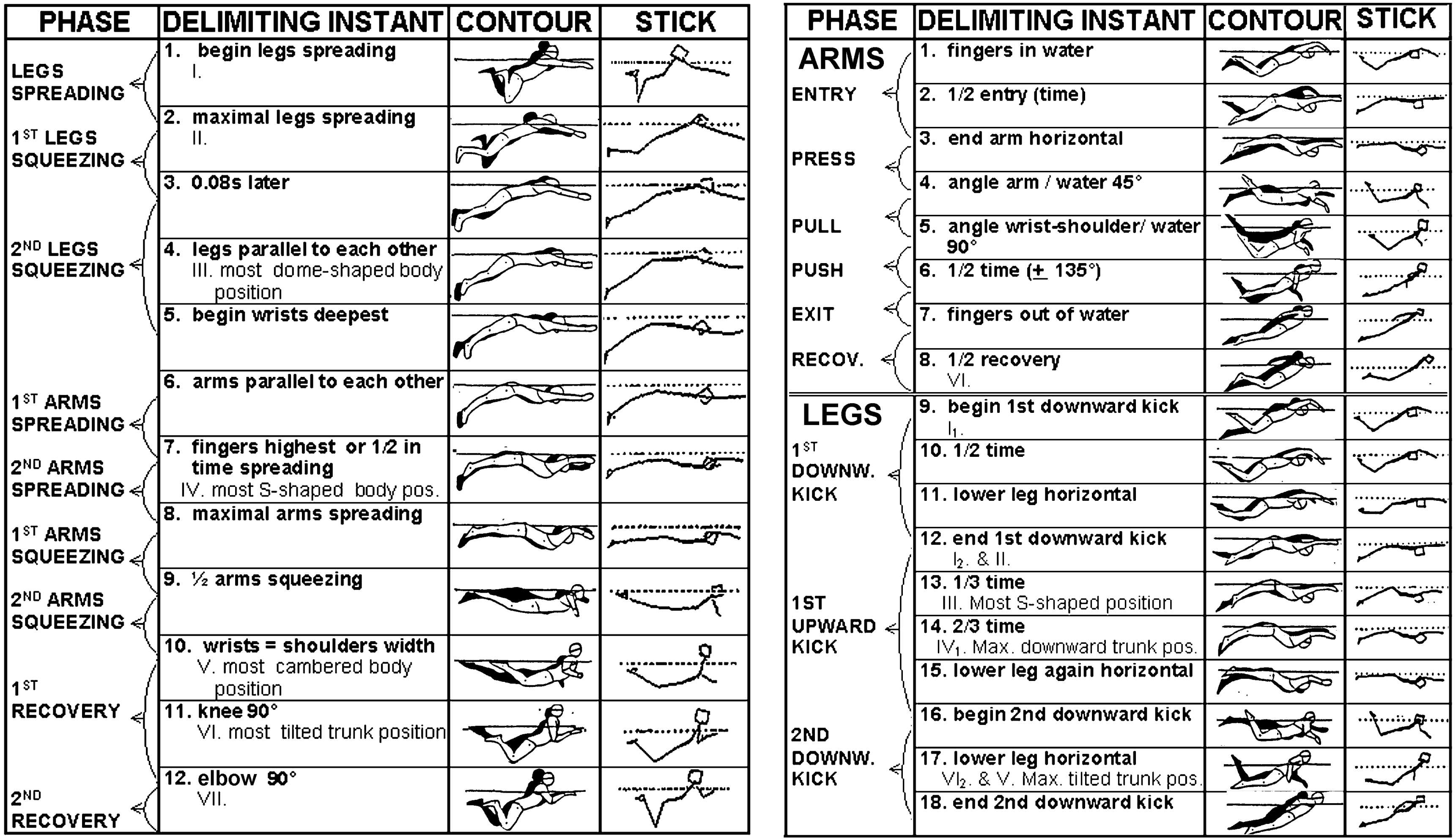



**Figure 2 - Contour drawings compared to stick figures for the digitised instants delimiting the phases (for one international level breaststroke and butterfly swimmer).**

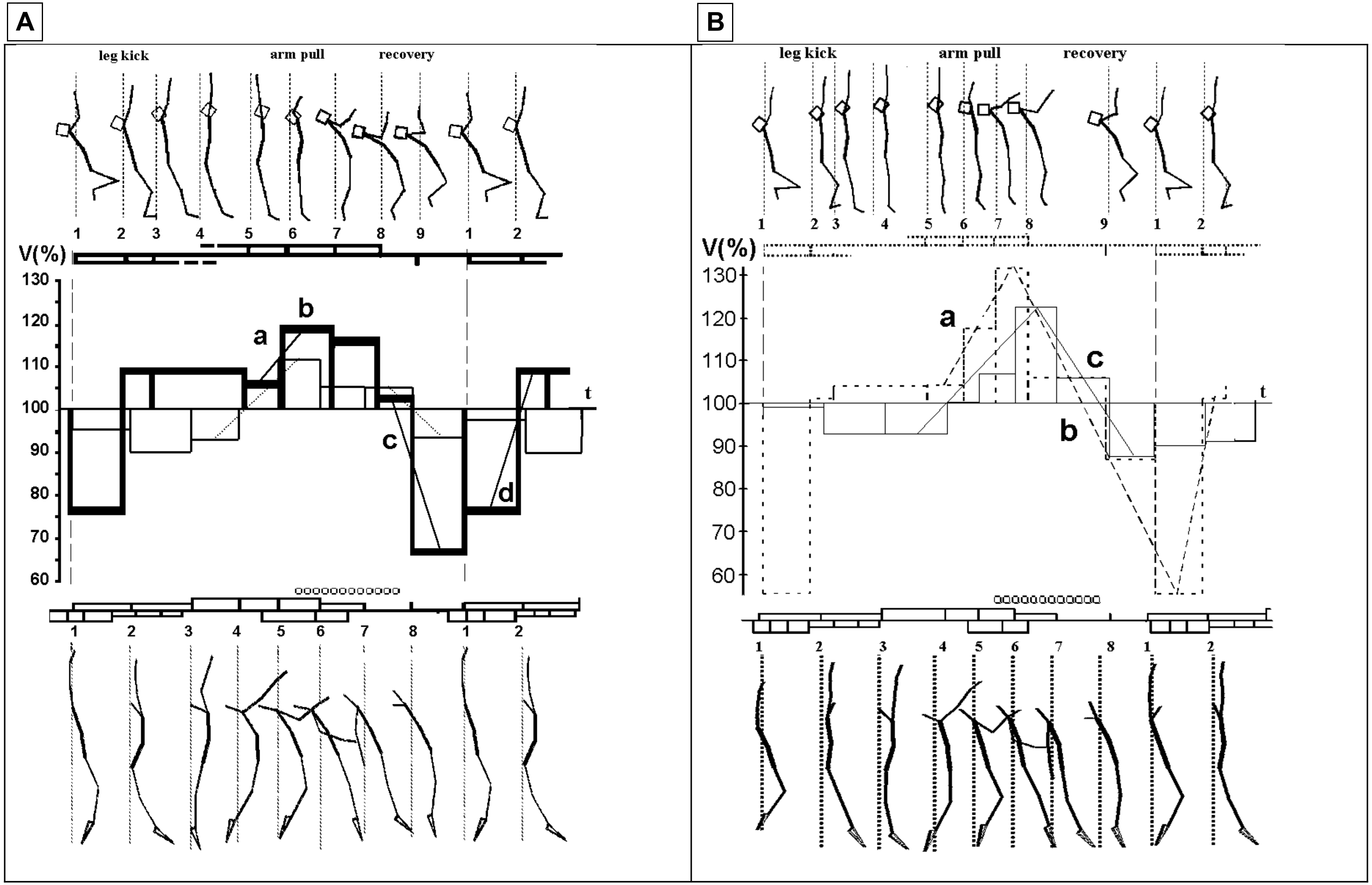



**Figure 3 - Comparison of the horizontal velocity variations of the CMbody in breaststroke and butterfly: (A) the 2 undulating variants and in (B) the 2 flat variants.**

**RESULTS AND DISCUSSION:**

**Movement Analysis.** In the two strokes, at the international level, there is much more velocity variation of the CMbody in the breaststroke than in the butterfly and much more in the flattest than in the most undulating variants:

- In the two flattest variants, in breaststroke a difference between the highest and lowest velocity peaks of 76.2% of the swimming velocity (131.4% - 55.2%) was measured and in butterfly of 34.7% (122.3% - 87.6%).
- In the two undulating variants, in breaststroke a difference of 52.9% of the swimming velocity (119.2% - 66.3%) was measured and in butterfly of 20.7% (111.1% - 90.4%).

1. SIMILARITIES IN THE TWO STROKES IN PROPULSION RELATED TO ACCELERATIONS OF THE BODY SEGMENTS ABOVE THE WATER SURFACE

   <u>The two most undulating variants</u> (Figure 3, A)

   During a large trunk cambering and a backward upper trunk rotation (when the largest part of the arm propulsion takes place) a relatively small increase in horizontal velocity of the CMbody occurs. The backward displacement of body segments above the water surface causes a decelerating transfer of momentum (see diagonal line, a).

   During body hydroplaning (when the last part of the arm propulsion and the first part of the arm recovery take place) the velocity is relatively well maintained (b). A forward-accelerated mass of water behind the body could push against the back and help to avoid too much deceleration of the CMbody. In butterfly, the fast forward arm swing above the water surface, combined with an upward kick, causes more propulsive transfer of momentum than only the upper arm in breaststroke. Consequently, in butterfly during this phase there is even no deceleration of the velocity of the CMbody.

   During the first part of the forward upper trunk rotation (when the second part of the recovery of the arms takes place), a decrease in velocity cannot be avoided (c).

   During the second part of the forward upper trunk rotation, with a body section still above the water surface (when the first part of the bottomward leg kick takes place), an early increase in velocity occurs. The forward displacement of body segments above the water surface causes an accelerating transfer of momentum (d).

   <u>The two flattest variants</u> (Figure 3, B)

   During the entire arm propulsion, a similar and large increase in velocity occurs (a).

   During the entire recovery of the arms, a similar and large decrease in velocity occurs (c) and in the flat breaststroke variant even during the backward spreading of the legs (b).

2. SIMILARITIES IN THE TWO STROKES IN PROPULSION RELATED TO BODY WAVING

   From the undulating breaststroke, to the flat and to the undulating butterfly variants, increasing amplitudes are measured:

   - In knee hyper extension: respectively 9.4°, 13.5° and 15.6° (complementary angles)
   - in S-shape of the body: respectively 43.4°, 62.2° and 80° (sum of the complementary angles in the middle of the trunk, hips and knees) (Figure 4, E-F).

   Consequently, an increasing amount of water could be displaced backward in the curves of the body, generating propulsion (Gray 1933, Persyn 1974).

   In the most undulating butterfly variant, the downward leg kick starts more from the hips than in the flattest variant (-2.8° hyperextension versus 5.2° flexion), while in the flattest variant the kick starts more from the knees (68° versus 50° flexion) (Figure 4, a).

   Although the leg kicks differ in the two butterfly variants, the vertical displacements of the toe and the hip (relative to a fixed background) are almost equal (respectively 22% and 7% of the body length). But, the vertical displacement of the shoulder is much deeper in the most undulating than in the flattest variant (respectively 12.9% versus 8.8% of the body length) (Figure 4, g). This deep upper trunk and arm displacement counter-acts the downward kick to keep the CMbody on the same horizontal line. Moreover, the javelin-throw-like stretching of the shoulder girdle prepares an effective arm pull.

In order to determine an individual's appropriate amplitude of undulation in breaststroke, it is advised to consider the amplitude in butterfly. At international level, a statistical relation was found, indeed, between the amplitude of undulation in butterfly (which is a natural movement) and in breaststroke (where undulation is still in evolution). The highest correlation occurs in the most S-shaped body position (.66***).

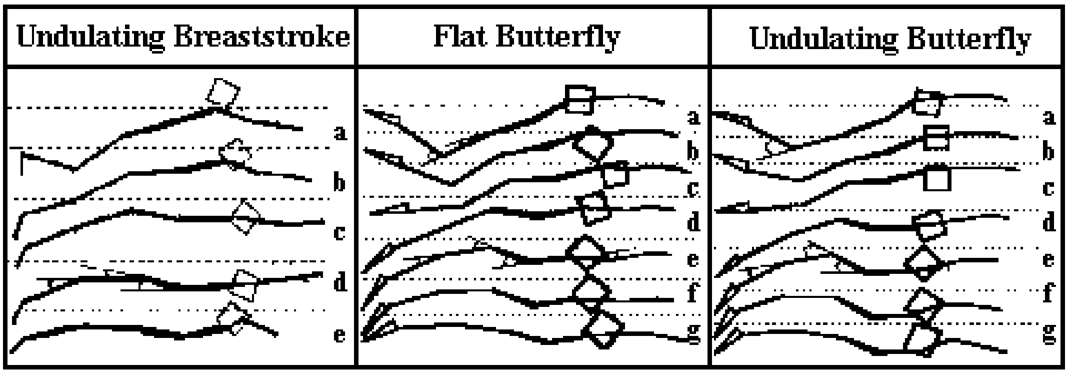



**Figure 4 - Mean stick figures of the down- and upward leg kick in the undulating breaststroke and two extreme butterfly variants (N= 4-6).**

**Body Analysis.** In Figure 5, the mean flexibility (a) and strength (b) scores (strength corrected for body weight) of the men and women separately are specified in the total reference population of women and of men, combined in one profile (N = 267 women, 307 men). The global pattern of the mean flexibility and strength scores of the swimmers in the four style variant groups is visualised by broken lines.

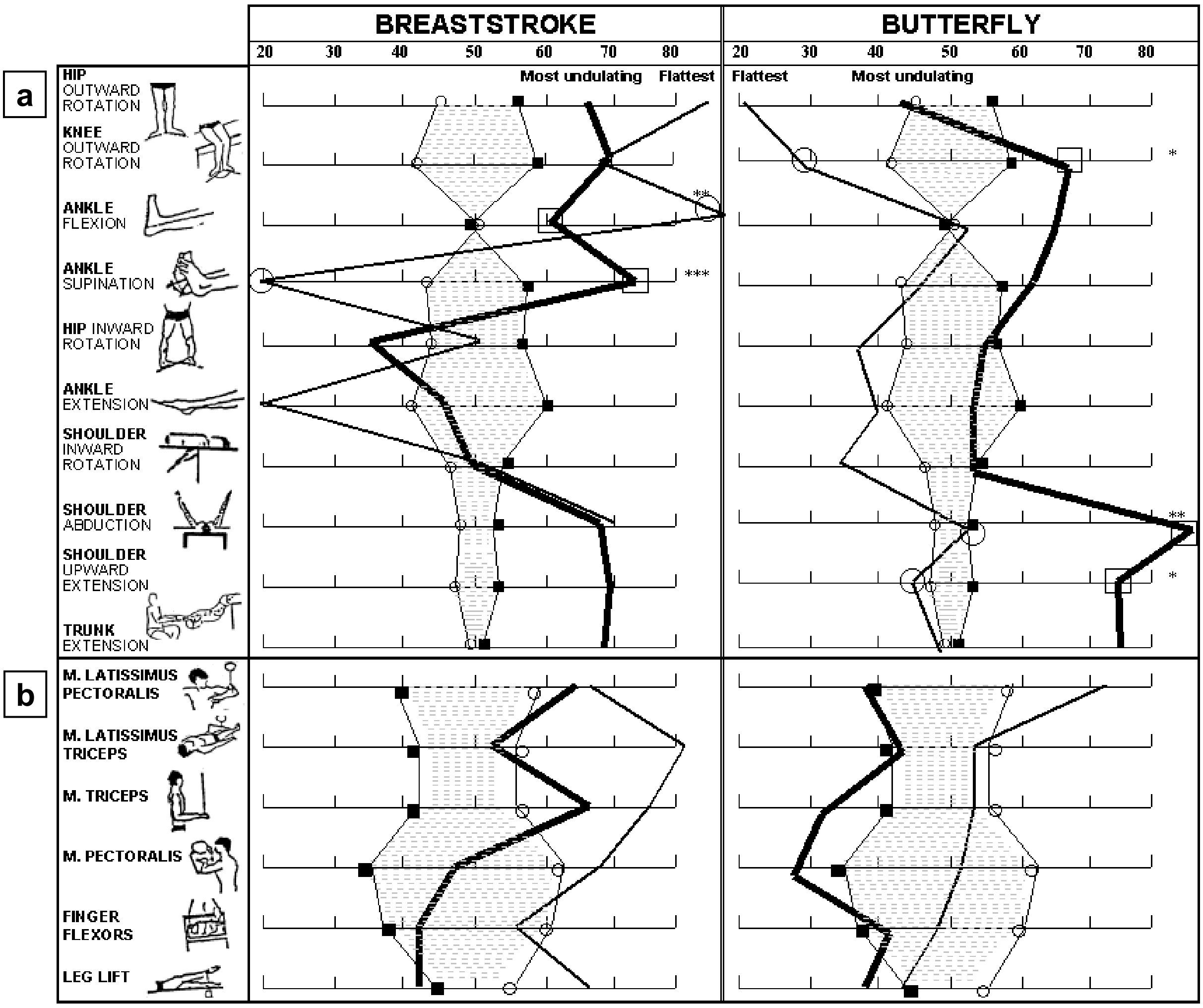
The differences in flexibility scores of butterfly are evident, and certainly in shoulder and trunk flexibility. The scores of another variant (average undulating) are situated between the two broken lines; in fact, in this variant men and women have almost the same flexibility scores. From the flattest to the most undulating variants, the systematically higher flexibility scores in butterfly correspond, thus, with the increasing amplitude of undulation. In breaststroke, there is not the same systematic evolution in scores because in the flattest variant there is no undulation at all (Figure 3 B).

Moreover, in Figure 5, statistically significant differences (t-test) between the scores in the style variant groups were indicated. Specific differences between flexibility scores of, for example, the ankle in the extreme style variants in breaststroke could explain very different propulsive concepts:

- Women in the most undulating variant have a high score for ankle supination, which is significantly higher than the score of men in the flattest variant (t-test, $p<0.001$). Ankle supination allowed to position the sole of the foot like a dolphin tail during the downward part of the kick, and like a propeller blade during the first part of the squeezing of the legs.
- Men in the flattest variant have a high score for ankle flexion, which is significantly higher than the already high score of women in the most undulating variant (t-test, $p<0.01$). Ankle flexion is required to position the sole of the foot sufficiently perpendicular to the almost horizontal longitudinal axis of the trunk, during the first part of the squeezing of the legs (Figure 3,B).

The breaststroke swimmers are generally stronger in the upper limbs than the butterfly swimmers (Figure 5, b). In breaststroke in the most undulating variant, the women have scores for m.latissimus-pectoralis (64%) and m.triceps (66%), which are even higher than the mean scores of the total reference population of men (58% and 56% respectively). This strength, combined with a high flexibility score for shoulder abduction and upward extension and for trunk extension, allows the upper trunk to rotate backwards during the last part of the squeezing of the arms and to be lifted partly above the water surface.

The previous data are interesting to guide the dry land training. In addition, these physical characteristics determine the best stroke and style variant per individual with a mean error in performance calculation of less than 3%. This 'prediction' is based upon the smallest difference between the individual scores and the mean of the physical characteristics per style variant (broken lines in Figure 5) (Zhu & Persyn & Colman 1997).




Mean scores of:

- : Reference population of women (N = 267).
- : Reference population of men (N = 307).
- : Most undulating variant of women in breaststroke (N = 8); in butterfly (N = 7).
- : Flattest variant of men in breaststroke (N = 5); in butterfly (N = 10).
- : □ ○ Significant differences (at least p<.05).

**Figure 5 - Flexibility and strength characteristics of the most undulating and flattest variant in breaststroke and butterfly, situated in one profile of the total reference population of women and men combined (N = 574).**

**CONCLUSION:** In the undulating variants, propulsion lasts longer during the stroke cycle than in the flat variants. This can be explained by a forward transfer of momentum from a mass of water, behind the back, and from a body section accelerated above the water surface (combined with a relative backward displacement of the feet during a propulsive phase).

A complete kinesiological diagnosis can only be made when a screening of the physical characteristics is combined with the screening of the style (the amplitude of undulation and more detailed movement variables) and the calculation of the velocity variation of the CMbody. To automate this complete kinesiological diagnosis, these methods are being implemented in a kind of expert system (Figure 1).

Meanwhile, swimming experts must be educated to use this system in the field, by means of a multimedia CD-rom, containing interactive didactical software, videotapes, and some written materials about the methods. Four kinds of interactive PC-programs are being collected in this CD-Rom with the following educational intentions: providing the theoretical concepts, applications in case studies, diagnosis and advice and prediction of the evolutions of the body characteristics (structure, flexibility an strength) in the best variant and, most importantly, of the performance.

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