THE NEED FOR MEASUREMENT OF TRUNK FLEXION IN BREASTSTROKE MOVEMENT ANALYSIS

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The purpose of this study was to examine the problem related to the undulating variant in breaststroke. In most of the video-analysis systems that are available, the trunk is represented as one straight line, namely from shoulder to hip, instead of dividing the trunk into segments. The objective of this article is to determine the point at which a straight trunk is obtained in the analysis. However, an explanation can be found in the very low swimming velocity variation. Interpretation of the data is made in three critical phases. During the second part of the arm compression phase, the body is not cambered but 'broken. As a result, the upper trunk cannot decelerate to any degree, above the water surface and conversely, water cannot be accelerated behind the lower trunk. Consequently, in order to level off the velocity variation, during the first part of the recovery, water cannot push against the back; and during the propulsion phase of the legs, no forward transfer of momentum from the upper trunk can be expected.

KEY WORDS: breaststroke swimming, trunk flexion, movement analysis

INTRODUCTION: A specific problem in the movement analysis of a breaststroke swimmer is the reconstruction of the disturbed image of the body in both water and air. In the case of extreme trunk, shoulder and hip mobility when undulating, a correct calculation of the centre of mass of the body (C.M.body) is required. Van Tilborgh et al. (1988) developed a 16mm film-analysis system to calculate the C.M. body for competitive swimmers, taking into account the undulation. Colman et al (1990;1998) adapted the system for video-analysis and improved the reconstruction of the disturbed image (on an Amiga PC).
In the last ISBS Congress, mean stick figures were presented for five of the most undulating and five of the least undulating breaststroke specialists competing at an international level (Persyn and Colman 1999). 39% less velocity variation of the C.M.body per stroke cycle was found in the most undulating variant than in the least undulating variant. In the most undulating variant, the highest velocity peak (in the least undulating variant) had levelled off. This could be explained by a swing-like upward rotation of the cambered body, which resulted in a backward transfer of momentum from the upper body when in the air, while the lower trunk was pushed forward against the water (Fig. 1: contour figures). The lowest velocity peak was levelled off, as a result of inverting the cambered body to create a dome-shaped body. This resulted in a forward transfer of momentum from the upper body while the lower trunk was pushed up and backward.
The concern with the study of the most undulating variant is that in most of the video-analysis systems available, the trunk is represented by only one straight line, namely from shoulder to hip. Consequently, the upper trunk cannot rotate backwards and forward separately from the lower trunk and the lower trunk cannot be pushed forwards and backward.
The object of this article is to investigate whether or not, in analysis using the straight trunk (and the calculation of the CMbody specific for competitive swimmers), developed by Van Tilborgh, an explanation can be found for the very low velocity variation of the CMbody.

METHODS: To record the swimmer using two media, and in the disturbed zone between, one camera and a periscope was used to obtain a side view. This set-up was also rotated to obtain a close-up view. To allow for a fast movement analysis and diagnosis (in about 30 min), only 9 typical instants in the cycle were selected from side and front view recordings to be digitised (Colman 1990).
In the analysis of the flexed trunk, the phases obtained were not only representative of the leg kick, the arm pull and the recovery phase, but also for undulation, by measuring the

angles of the hip, middle trunk and shoulder. Interpretations were then made in three critical phases from the analyses with a flexed and with a straight trunk.

RESULTS AND DISCUSSION: In the least undulating style variant, the highest C.M.body velocity peak, occurred during the second part of the arm compression phase and the lowest peak during the propulsion phase of the leg (Fig. 1, G and A). In this variant, the difference between these peaks amounted to 77% of the mean swimming velocity however, this difference is considerably smaller in the most undulating variant (52.9%). Using the analysis with a straight trunk, this difference is even less (only 49.7%).

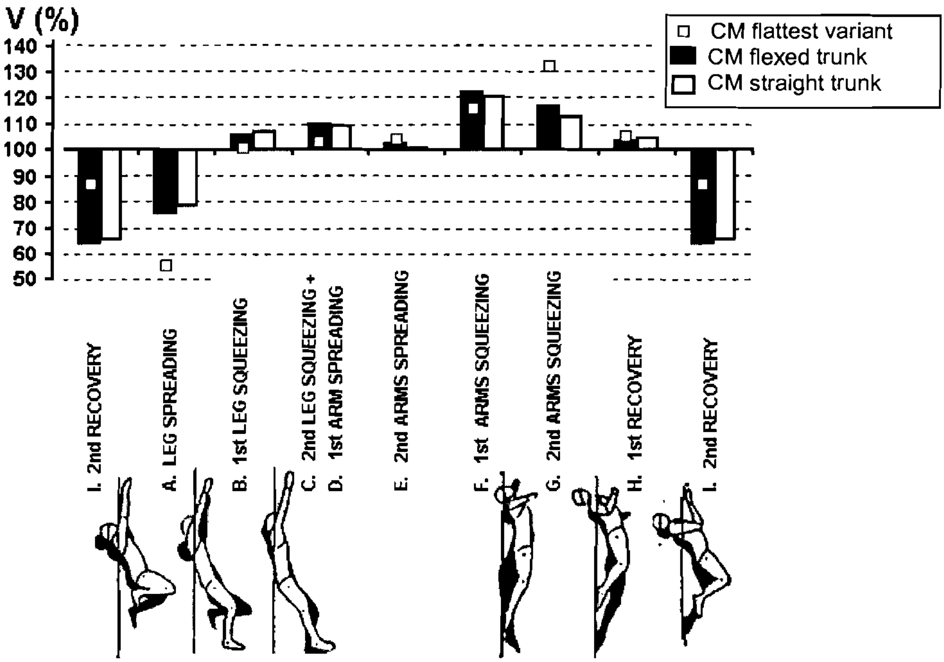

Figure 1 - Velocity variation of the CMbody per phase in % of the mean swimming velocity. The results of the most undulating variant are compared when straight and a flexed trunk are digitised.

Using the analysis with a flexed trunk. During the second part of the arm compression phase, in the most undulating variant, the velocity of the CMbody was 15% lower than in the least undulating variant (Fig. 1, G). The velocity of the swing-like, backward upper trunk rotation (from 36° to 64° relative to the horizontal) amounts to 195°/s (Fig. 2, a, G). Conversely, the forward velocity of the lower trunk (the velocity of the hip and of the middle trunk) remains approximately the same as during the preceding phase (Fig. 2, b, F). Consequently, by using this analysis, the levelling off of the C.M.body velocity can be explained by a backward transfer of momentum of 29% of the body mass above the water surface (the upper trunk, which includes the shoulder girdle, upper arm and head).
The hypothesis for this study was developed, which stated that the energy lost by this backward transfer of momentum and by pulling water behind the lower trunk, is recuperated during the following two critical phases.

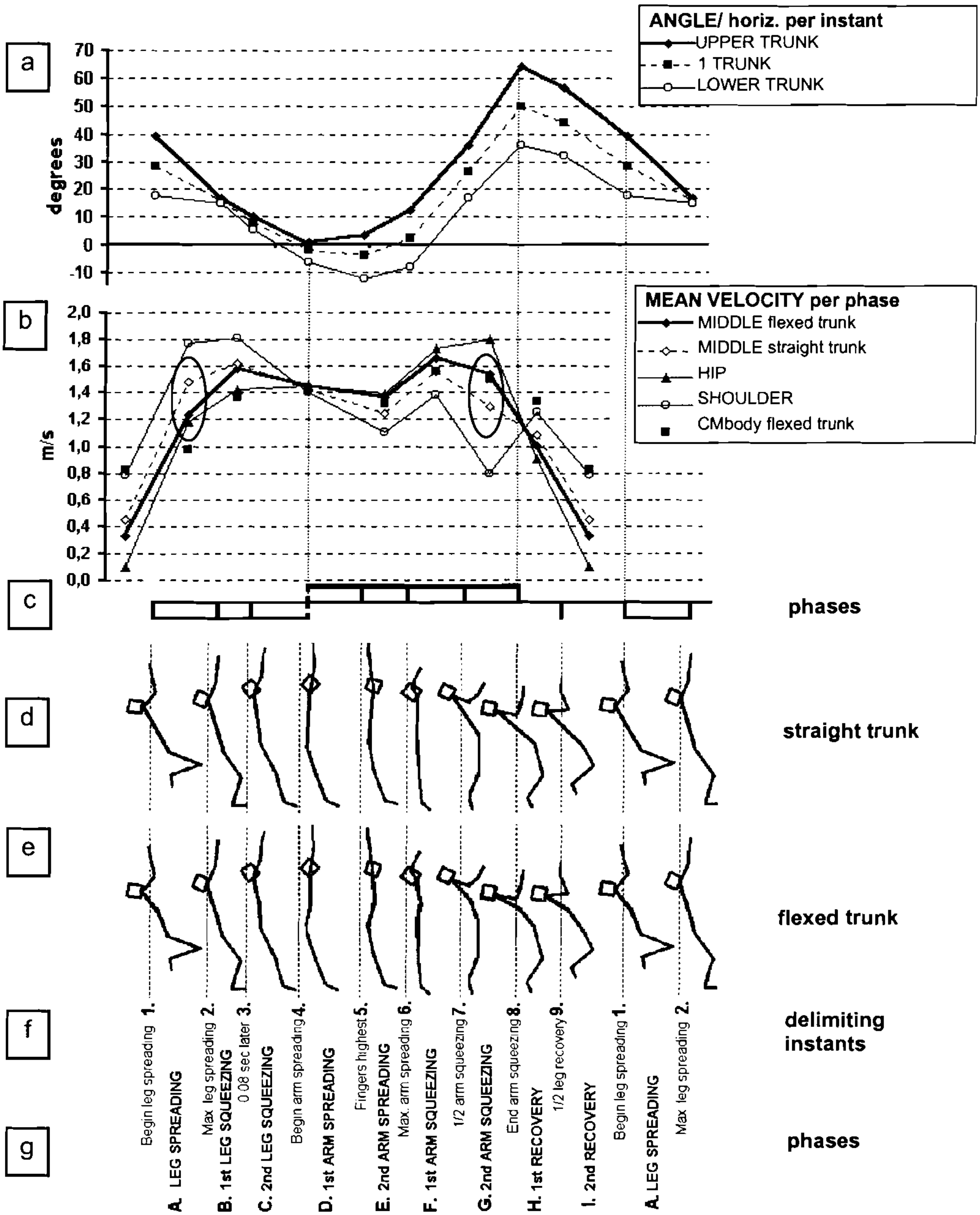

Figure 2 – Differences in angles (relative to the horizontal) and in mean velocities per phase between the analysis with a flexed and with a straight trunk.

a. During the first part of the recovery phase, the velocity of the CMbody is only 17% slower than in the preceding phase (versus 27% in the least undulating variant) (Fig. 1, G-H). This could be explained as a result of the inertia of the mass of water, being pulled forward behind the lower trunk during the preceding second part of the arm compression phase, as it continues to push against the back (Fig. 2, e, H).
b. During the first part of the recovery, the velocity of the CMbody is only 17% slower than in the preceding phase (versus 27% in the flattest variant) (Fig. 1, G-H). This was explained because the inertia of the mass of water, pulled forward behind the lower trunk during the preceding second part of the arm squeezing, continues a while to push against the back (Fig. 2, e, H).
c. During the leg spreading, the velocity of the CMbody is 9.5% faster than in the preceding phase, the second part of the recovery (versus 32% slower in the flattest variant) (Fig. 1, I-A). This was explained by three phenomenon's:
   - the forward upper trunk rotation (from 39° to 17°), predominantly above the water surface, amounts to a velocity of 136°/s (Fig. 2, a, A).
   - the back is kyphosed and above the water surface and the abdomen is flattened, reducing the form drag (Fig. 1: contour figures).
   - This dolphin-like entry of the body causes a high muscle tension in the abdomen and around the pelvis, which consolidates the basis for the downward leg kick.

Using the analysis with a straight trunk. During the second part of the arm compression phase, the body is not cambered but 'broken' (Fig. 2, d, G). Thus, there is no swing-like rotation of the upper trunk. The straight trunk rotates from 26° to 50° and thus less backward (Fig 2, a, G), while the forward velocity of the middle of the trunk is 0.24m/s slower (than using the analysis with the flexed trunk) (Fig. 2, b, G). Consequently, using this analysis, although the levelling off of the CMbody velocity can be explained, there is no support for the hypothesis of a backward transfer of momentum, nor of pulling water behind the lower trunk.
a. The push against the back during the next phase, as the first part of the recovery phase.
b. During the leg propulsion phase, slightly more acceleration of the CMbody (than using the analysis with a flexed trunk) cannot be explained (Fig. 1, I-A). Less forward upper trunk rotation velocity (from 28° to 16°, versus 39° to 17°) has a velocity of only 89°/s (versus 136°/s) (Fig. 2, a, A). However, the forward velocity of the middle of the trunk is 0.25 m/s faster (than using the analysis with the flexed trunk) (Fig. 2 b, A). Therefore, there is no support for the hypotheses of a forward transfer of momentum but rather a deceleration of the CMbody can be expected, comparable to the phenomenon in the least undulating variant (Fig. 1, A).

CONCLUSION: Although Van Tilborgh et al (1988) received the Archimedes Award in Bielefeld (1986) presenting a 16 mm film-analysis system, by taking into account body undulation, most of the video-analysis systems still digitise a straight trunk. This could be explained, on one hand, because Colman developed the analysis system on an Amiga PC, which has almost disappeared. On the other hand, the systems that are available on the present market have not been adapted specifically to solve the reconstruction problem related to the image of the swimmer in two media and in the nebulous zone in between. In the present co-operative relationship that exists with the biomechanics of swimming, the reconstruction of the global body should be generalised.

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