Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

THE EFFECT OF WEARING A CAP ON THE SWIMMER PASSIVE DRAG

Daniel A. Marinho[1,2], Vishveshwar R. Mantha[2,3], Abel I. Rouboa[2,3], João P. Vilas-Boas[4,5], Leandro Machado[4,5], Tiago M. Barbosa[2,6] and António J. Silva[2,3]

Department of Sport Sciences, University of Beira Interior, Covilhã, Portugal[1]
Research Centre in Sport, Health and Human Development, Portugal[2]
Department of Sport Sciences, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal[3]
Faculty of Sport/CIFI2D, University of Porto, Porto, Portugal[4]
Porto Biomechanics Laboratory (LABIOMEP), University of Porto, Porto, Portugal[5]
Department of Sport Sciences, Polytechnic Institute of Bragança, Bragança, Portugal[6]

The purpose of this study was to analyse the effect of wearing a cap on swimmer passive drag. A computational fluid dynamics analysis was carried-out to determine the hydrodynamic drag of a female swimmer's model: (i) wearing a swimming cap and; (ii) with no cap. The three-dimensional surface geometry of a female swimmer's model with cap and with no cap was acquired through standard commercial laser scanner. Passive drag force and drag coefficient were computed with the swimmer in a streamlined position. Higher hydrodynamic drag values were determined when the swimmer was with no cap in comparison with the situation when the swimmer was wearing a cap. In conclusion, one can state that wearing a swim cap may positively influence swimmer's hydrodynamics.

KEY WORDS: CFD, swimming, model, sports equipment.

INTRODUCTION: Swimming velocity depends on the interaction between hydrodynamic drag force and propelling force. Aiming to achieve higher velocities the swimmer should minimize the hydrodynamic drag force resisting forward motion and maximize the propelling force. Regarding the first aim, several studies analyse the effect of wearing different equipments on hydrodynamic drag, with special attention to the use of swimsuits (e.g., Mollendorf et al., 2004; Pendergast et al., 2006; Toussaint et al., 2002). Regarding the benefits of wearing the new generation of swimsuits, it seems their use allows to mold the swimmer's body into a more streamlined shape, reducing the hydrodynamic profile and minimizing oscillations/vibrations in muscles and other body wobbling masses that might disturb the flow (Marinho et al., 2009). Nevertheless, the research regarding the effect of wearing a swim cap on hydrodynamic drag is not reported, although its use is almost consensual on reducing changes on the body shape of the head, especially on female swimmers with long hairs. Therefore, the purpose of this study was to analyse the effect of wearing a cap on a female swimmer passive drag.

METHODS: The numerical simulation of the fluid flow around the two swimmer's models was carried out in Ansys Fluent™ 6.3 commercial software (Ansys, Canonsburg, Pennsylvania, U.S.A.). The simulations are based on Finite volume method of discretization. The three-dimensional surface geometry model was acquired through standard commercial laser scanner *Vitus Smart XXL 3D* body scanner (Human Solutions Company, Kaiserslautern, Germany), as used previously (Bixler et al., 2007; Leong et al., 2007). The subject of this study was an Olympic level female swimmer (height 1.66m, weight 55.0kg, age 23 years-old). The swimmer was fully informed of the aims of the participation in the investigation and voluntarily agreed in participation, with the signing of written informed consent. The swimmer was in rest along the body scans. Each scan took an average of 20 minutes. Care was taken to limit differences in alignment of the individual scans for the two situations, by fixing the

position of feet, maintaining similar vertical and horizontal alignment in respective scans and also the stationary pose with control of breadth (Lashawnda & Cynthia, 2002) during the actual moment of acquiring the scan. The swimmer presented her arms extended above the head (shoulders flexed), with one hand above the other (streamlined position). The three-dimensional geometric models were used later for analysis through computational fluid dynamics simulation.
The quadrilateral computational domain of 20m length, 2.5m breadth and 1.5m height with inlet at 5m upstream of the swimmer model was prepared in Gambit™ preprocessor (Ansys, Canonsburg, Pennsylvania, U.S.A.). The computational domain consisted of about 11 thousand tetrahedral grid cells. The passive drag was determined with the swimmer model at a depth of 0.75m. Drag force and drag coefficient were computed for flow velocities of 1.5, 2.0 and 2.5m/s.

RESULTS: Figures 1 and 2 present the values of drag force and drag coefficient for the female swimmer's model in the two analysed situations, wearing a cap and with no cap, respectively. As one can observe, the situation when the swimmer is with no cap presented higher hydrodynamic drag values than the situation when the swimmer is wearing a cap. For instance, for a flow velocity of 2.0m/s the decrease of drag force and drag coefficient when the swimmer is wearing a cap is about 17% and 13%, respectively, comparing with the situation when the swimmer is gliding without a swim cap.
Moreover, one can verify that drag force increases with flow velocity and the opposition situation occurs for drag coefficient.

DISCUSSION: The purpose of this study was to analyse the effect of wearing a cap on a female swimmer passive drag. Numerical simulations were applied to analyse drag force and drag coefficient in both situations. The main data has shown that the use of a cap during the swimming glide can lead to a ~15% decrease on passive drag.
Computational fluid dynamics methodology is based on computer simulations, allowing to test several conditions and to obtain the best result, without physical/experimental testing. This methodology was developed to be valid and accurate in a large scope of fluid environments, bodies and tasks, including sports, being scientifically assumed to have ecological validity for swimming research (Bixler et al., 2007; Marinho et al., 2010). On the other hand, reverse engineering procedures were used to obtain accurate digital models of the female swimmer. Several studies have shown the great potential offered by reverse engineering procedures for developing true digital models of the human body to improve the prediction of hydrodynamic forces in swimming (Bixler et al., 2007; Lecrivain et al., 2008).

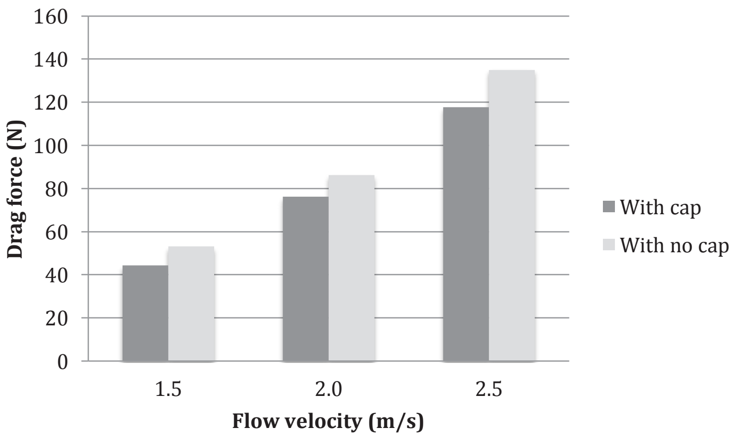

Figure 1: Values of drag force for the female swimmer's model with cap and with no cap.

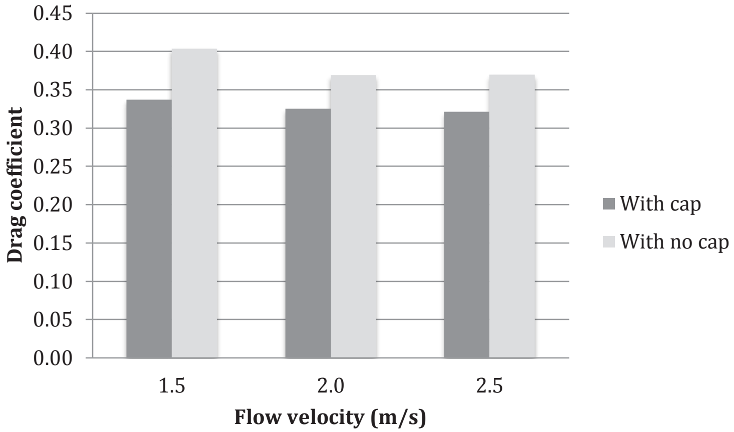

Figure 2: Values of drag coefficient for the female swimmer's model with cap and with no cap.

Regarding the drag coefficient values, one can note that there was an inverse relationship between this variable and the velocity flow. The drag coefficient decreased as velocity increased. This situation was reported previously both on experimental and numerical investigations in swimming (Lyttle et al., 1999; Bixler et al., 2007) for swimmers wearing a cap. Moreover, the current results are very similar to the ones presented by Bixler et al. (2007), using numerical simulations on a three-dimensional model of the human body of an elite swimmer (values of about 0.30 for velocities ranging from 1.5 to 2.25m/s). Concerning drag force, similar data was also obtained. Lyttle et al. (1999), at the lower velocity studied (1.6m/s), and at the deepest studied towing position (0.6m deep), reported values within the range of the current study (58.1N). Bixler et al. (2007) found drag force values of 31.58 and 55.57N for velocities of 1.5 and 2.0m/s, respectively, with the human model at a prone position with the arms extended at the front. In this position we found drag force values of 44.41 and 76.23N (wearing a cap) and of 53.12 and 86.35N (with no cap), for velocities of 1.5 and 2.0m/s, respectively.

Considering these results, we believe the current numerical simulation allowed to determine the difference on passive drag between to wear or not to wear a swim cap during the gliding. There has been some research on the effects of wearing different swimsuits on hydrodynamic drag (Mollendorf et al., 2004; Pendergast et al., 2006; Toussaint et al., 2002). However, to the best of our knowledge, there is no evidence in the literature of the effects of wearing a swim cap in swimming. The reduction of ~15% on hydrodynamic drag during the gliding reported in this research should be confirmed with other studies, analysing swimmers of different level and different gender, since this study was performed with one single female swimmer. Additionally, some attempts should be carried-out to analyse the effects of wearing different types and shapes of swim caps and hair positions on hydrodynamic drag.

CONCLUSION: The results pointed out that there is an advantage of wearing a swim cap on swimming performance. The 15% decrease on hydrodynamic drag underlines the importance of the equipment on swimming hydrodynamics. Therefore, swimmers and their coaches should pay additional care on the selection of the swimming equipment during training and competition.

REFERENCES:

Bixler, B., Pease, D. & Fairhurst, F (2007). The accuracy of computational fluid dynamics analysis of the passive drag of a male swimmer. *Sports Biomechanics*, 6, 81-98.

Lashawnda, M. & Cynthia, L.I. (2002). Body scanning: effects of subject respiration and foot positioning on the data integrity of scanned measurements. *Journal of Fashion Marketing Management*, 6, 103-121.

Lecrivain, G., Slaouti, A., Payton, C. & Kennedy, I. (2008). Using reverse engineering and computational fluid dynamics to investigate a lower arm amputee swimmer's performance. *Journal of Biomechanics*, 41, 2855-2859.

Leong, I.F., Fang, J.J. & Tsai, M.J. (2007). Automatic body feature extraction from a marker-less scanned human body. *Computer-Aided Design*, 39(7), 568-582.

Lyttle, A.D., Blanksby, B.A., Elliott, B.C. & Lloyd, D.G. (1999). Optimal depth for streamlined gliding. In K.L. Keskinen, P.V. Komi & A.P. Hollander (Eds.), *Biomechanics and Medicine in Swimming VIII* (pp. 165-170). Jyvaskyla: Gummerus Printing.

Marinho, D.A., Barbosa, T.M., Kjendlie, P.L., Vilas-Boas, J.P., Alves, F.B., Rouboa, A.I. & Silva, A.J. (2009). Swimming simulation: a new tool for swimming research and practical applications. In M. Peters (Ed.), *Lecture Notes in Computational Science and Engineering – Computational Fluid Dynamics for Sport Simulation* (pp. 33-62). Berlin: Springer.

Marinho, D.A., Barbosa, T.M., Reis, V.M., Kjendlie, P.L., Alves, F.B., Vilas-Boas, J.P., Machado, L., Silva, A.J. & Rouboa, A.I. (2010). Swimming propulsion forces are enhanced by a small finger spread. *Journal of Applied Biomechanics*, 26, 87-92.

Mollendorf, J.C., Termin, A.C., Oppenheim, E. & Pendergast, D.R. (2004). Effect of swim suit design on passive drag. *Medicine and Science in Sports and Exercise*, 36(6), 1029-1035.

Pendergast, D.R., Mollendorf, J.C., Cuviello, R. & Termin, A.C. (2006). Application of theoretical principles to swimsuit drag reduction. *Sports Engineering*, 9, 65-76.

Toussaint, H.M., Truijens, M., Elzinga, M.J., Ven, A. van de, Best, H. & Groot, G. de. (2002). Effect of a Fast-skin "body" suit on drag during front crawl swimming. *Sports Biomechanics*, 1(1), 1-10.

Acknowledgement

The Portuguese Government supported this work by a grant of the Science and Technology Foundation (PTDC/DES/098532/2008; FCOMP-01-0124-FEDER-009569). The authors would like to thank the important contribution of the swimmer Sara Oliveira.