Measurements and Analyses of Load Torque for Underwater Training

Yasuhiko Hatanaka

Underwater training has been applied to rehabilitation and therapeutic exercise in medical care and physical fitness. Increase of the number of the elderly and middle-aged people with lifestyle-related diseases is becoming a social problem. As one of the solution to this problem, effectiveness of therapeutic exercise, especially underwater training is receiving attentions.

However, qualitative evaluation on underwater training effect or heuristics-based underwater exercise education has been done so far in practice. The problem is caused by the difficulty of kinetic analysis of the underwater motion of multi-link structure of human body with non-steady states.

As a basic research to solve the complex problem, this dissertation explore a new method to generate the various load patterns for underwater training and clarify the relationship between the motion patterns and the load torque patterns.

First, to generate various loads pattern, this dissertation proposes the load torque reduction system using underwater bubble environment. In order to demonstrate the effectiveness of the proposed system, a human leg model and a cylindrical model with one degree of freedom are utilized. As the result, it is confirmed that the torques of the human model and the cylinder model can be reduced with 50% and with 10%, respectively.

Next, to investigate the relation between as the load torque patterns and the motion patterns, time-scale transformation and iterative learning control are introduced in this dissertation. In the previous inverse dynamics method, it is necessary to estimate the accurate parameter values on the human body dynamics and fluid dynamics. In the iterative learning control, the required data to measure the torque are obtained without using parameter estimation and the time-scale transformation can form the torque pattern which corresponds to arbitrary motion patterns. Moreover, the use of the obtained data for underwater training is explained.

Furthermore, this dissertation discusses the effects of underwater training basing on the joint torque analysis of the patients with total knee arthroplasty. For the analysis of underwater walking training, the load torque patterns of the hip, knee and ankle during underwater walking are measured using a model with six degrees of freedom. Particularly, the motion and torque patterns of the patients with osteoarthritis are compared with those of the healthy adults by taking account of buoyancy effect.

Finally, this dissertation proposes a new measurement system of the joint torque of the human lower extremity using a wire-drive mechanism to overcome the limitation of the current inverse dynamics analysis techniques. It is confirmed that the joint torque patterns of the hip and the knee during typical motions, such as walking motion, can be measured with sufficient accuracy.