KINEMATIC ANALYSIS OF GAIT ACCORDING TO LOAD INCREASE OF %BW IN UNDERWATER LOCOMOTION

Che-Cheong Ryew, Gye-San Lee*, and Jin-Hyun Kim

Cheju National University, Jeju, Korea
*** KwanDong Univerity, Gangnung, Korea**

The purpose of the study was to verify the possibility applicable for exercise theraphy of underwater by investigation of exercise effect on the basis of result of kinematic analysis according to the loads of %BW of SCUBA apparatus loaded in underwater activities. The experimental method was based on 3D cinematography analysis on repeative gaits(3 times) according to the load of %BW of SCUBA apparatus with very skilled diver in underwater activities in pool of 5m underwater depth(25m X 25m X 5m). When considering kinematic variables from analysis, load increase of %BW was resulted in more stable gait by generating a negative buoyancy counteracting effect of positive buoyancy. Also It could be considered that a method minimizing buoyancy & resistance of water in course of propulsion was to increase to a specific level of the load of %BW. That resulted in more stable & efficient gait. When considering the above, It will be assumed that improvement of exercise and therapy effect of underwater could be elevated by proper application the relationship of resistance & propulsion in condition submerged of whole body.

KEY WORDS: Load of %BW, underwater gait, underwater activity, SCUBA Diving

INTRODUCTION:

Human gait through bipedal locomotion has functional mechanism of lower extremities requiring interaction and coordination of intersegments. In general elapsed time in normal gait cycle was divided into largely 60% in supporting and 40% in swing. but might be different according to several pathological & working environment of gait. These abnormal gait had been concerned in exercise therapeutics and work efficiency. Chung, Chul-Soo etal(2003), Kim, Ro-Bin etal(2005), Eun, Seon-Deok(2006), Yoon, Suk-Hoon(2007) had investigated into the abnormal gait posture in rehabilitation & elderly. The previous studies on the gait had been concentrated on the gait of normal & abnormal patients of lower extremity, a pregnant, backpack-loaded worker, obesity, athletes and height of heel etc. from infantary to old age. The contents studies preceded consisted of efficiency, symmetry, velocity and posture according to change of load during gait. In a recent, SCUBA diving activity related with exercise therapy in underwater had been increased. Particularly Ju, Sung-Bum etal(2005) and Kim, Hyeon-Ju etal(2006) proved that submerged exercise program in underwater resulted in positive exercise effects. Locomotion in underwater environment could be performed with weighted body system to body for counteracion of buoyancy effect within the radius of work area. Ryew, Che-Cheong etal(2007) suggested that charecteristics ofl loads during gait according to loads of %BW of SCUBA apparatus in gravitational situation was divided into two category between lighter load of %BW(Load of 0%BW-10%BW) and heavier load(load of 25%BW-40%BW). He concluded that the optimal load of %BW moveable easily in rough diving field with SCUBA apparatus was proven to be load of 20-25%BW. That is, it is necessary to was to verify the possibility to apply for exercise theraphy of underwater by investigation of exercise effect on the basis of result of kinematic analysis according to the loads of %BW of SCUBA apparatus loaded in underwater activities. For this, We need first to present comparable kinematic data during underwater gait, second to present optimal load of %BW for normal gait in underwater situation.

METHOD:

The subject participated was a male diver experienced about 1,000 times in various diving point with age(28), height(176cm), weight(78kg) and performed each 3 times repetitive gait

experiment for the same load by each loads of %BW. The experimen was performed in regular waterpool(width 5m x depth 5m x length 25m). The equipments used for 3D cinematograph analysis was consisted of digital cam code 2ea(30f/s, VX-2000, Sony), control point box for DLT(2m x 2m x 1m, Visol.), LED(8555, V-Teck), Light(2ea) and Kwon3D Motion Analysis Package(ver3.016, Visol) for 3D motion analysis. Two stationary 45° angled-camera were used to capture the control point box for DLT, later remove the control box and the subject's gait motion according to the loads of %BW. The subject's 21 body joints were attached with reflex marker for easy digitization and performed every 3times per a gait on the each load of %BW within the range of control box point.
Direction was set to forward(y-axis), lateral(x-axis), and vertical(z-axis) to the gait progression. Analysis model was defined as total 21 joint with 17 segments and used the body segment parameters of Plagenhoef, S. C. etc.(1983). Independent variables of load were consisted of load of 0%BW(only body weight), BW + 10%BW(weight belt), BW + 25%BW(weight belt + 1 air tank), BW + 40%BW(weight belt + 2 air tank). Analysis phases & events were classified into 4 phases and 5 events during 1 stride of right leg ; supporting① swing, stance, supporting② phases and Heel-Takeoff, Toe-Takeoff, Heel-Touchdown, Toe-Touchdown, Heel-Takeoff of events. 3D coordination was obtained from DLT of Abdel-Aziz & Karara(1971) after synchronization and interpolation(interval o.o1sec.) used 3rd spline function on the basis of an extracted pair of 2D coordination as a result of digitization used Kwon3D motion analysis program(Kwon, 2004). The error from noise was smoothed(6Hz) using low-pass filter of Butterworth. Calculated datas from the 3D coordination consisted of temporal, linear kinematic, and angular kinematic variables were normalized by each phases.

RESULTS AND DISCUSSION:

Mean±SD of all kinematic variables analysed by gait phases during 1 cycle with loads of %BW of SCUBA appratus in underwater locomotion were summarized in table 1. Variables compared and analysed consisted of temporal, linear, angular kinematics by phases according to load increase of %BW. Summerized data in the table was Mean±SD of all loads of %BW.

Temporal: Mean elapsed time for 1 stride was 8.82±1.69sec. and each phase showed the order of 3.83±.80sec.(43.42%) of supporting①, 2.75±.30sec(31.17%) of supporting②, 1.98±.91 초(22.44%) of airphase and .24±.18 초(2.72%) of touchdown in all the load of %BW. When considering the results, the more additional the load of %BW, the less elapsed time and the more stable gait when added the load of %BW. When compared with 60% in support & 40%in swing(A.E. Barr, S.I. Backus, 2001) and 57.98% in supporting & 34.34% in airphase as 1.05sec. of total elapsed time 1.05sec(Ryew, Che-Cheong etal 2006), it showed significant difference in the study compared to results of previous studies.

Linear kinematics: Total mean displacement of COG in forward direction(Y-axis) in all loads of %BW was 125.89cm. It showed tendency that the more the load of %BW(40%), the longer displacement of COG while the less(0%) of load, the shorter displacement. When compared with the handicapped(55.1cm) of Kim, Moo-Young(2003) & normal gait(72.6cm) and 95.87cm under all loads of %BW of Ryew, Che-Cheong etal(2007), it showed longer displacement under all loads of %BW. Total mean velocity of COG in forward direction(Y-axis) showed the order of the load of 40%BW>25%BW>10%BW>0%BW, also the more the load of %BW, the faster velocity of COG in all phases. When compared with Ryew, Che-Cheong etal(2007), the results of the underwater study showed less velocity of 86.21cm/s in supporting①, 98.62cm/s in airphase, 125.99cm/s in touchdown, and 111.15cm/s in supporting② than gravitational gait

Table 2. Mean±SD of temporal, linear & angular variables by gait phases in all loads of %BW in underwater gait

phases		Supporting-1	Air-phase	Touch-down	Supporting-2
Elapsed time (sec,%)		3.83±.81 (43.42)	1.98±.91 (22.44)	.24±.18 (2.72)	2.75±.30 (31.17)
COG disp.(Y) (cm)		28.87±19.57	27.38±20.08	52.67±11.72	97.02±25.42
Velocity(Y) (cm/sec)		13.88±11.56	23.72±11.49	18.34±6.88	26.09±9.99
Ang. Disp. (deg)	Hip	169.17±6.23	137.62±20.75	109.94±9.40	144.50±21.86
	Knee	161.14±9.02	103.26±28.28	108.24±12.15	115.55±24.11
	Ankle	113.96±20.68	132.01±24.16	103.34±11.00	94.89±12.52
Ang. Vel. (deg./sec)	Hip	0.06±65.64	-27.63±70.18	-1.67±32.62	22.20±53.60
	Knee	10.09±54.29	-25.62±113.49	-23.65±40.43	13.41±64.66
	ankle	13.93±70.05	-26.07±85.26	24.51±66.96	-3.00±85.89
Forward tilting of trunk (deg.)		75.03±7.47	70.43±4.89	69.41±3.61	70.11±4.09
Right-left lateral tilting of trunk (deg.)		87.22±2.35	89.98±2.94	91.81±2.28	87.47±2.74

Angular kinematics: In angular displacement of lower extremities according to increase of the load of %BW, during airphase generated longest propulsion in 1 stride, the range of hip flexion showed the order of load of 0%BW>10%BW>25%BW>40%BW. Propulsion during airphase was performed on the condition of the more the load of %BW, the more flexion. The range of knee flexion during airphase showed the order of load of 0%BW>10%BW>25%BW>40%BW, also propulsion during airphase was performed on the condition of the more the load of %BW, the more flexion. The range of ankle flexion during airphase showed the order of load of 10%BW>0%BW>40%BW>25%BW, propulsion during airphase was performed irregularly regardless of the load of %BW. In angular velocity of lower extremities according to increase of the load of %BW, the largest propulsion was generated during airphase in 1 stride, the magnitude of hip angular velocity showed the order of load of 40%BW>25%BW.>10%BW>0%BW . Propulsion during airphase was performed on the condition of the less the load of %BW, the less angular velocity. The range of knee flexion during airphase showed the order of load of 40%BW>25%BW.>10%BW>0%BW, also propulsion during airphase was performed on the condition of the less the load of %BW, the less angular velocity. The range of ankle angular velocity during airphase showed the order of load of 25%BW>40%BW.>10%BW>0%BW , also propulsion during airphase was performed irregularly regardless of the load of %BW. That is, considering the fact that performed on the more the load of %BW, the faster flexion in knee & hip angular velocity during airphase generated longest propulsion in 1 stride, It was assumed that it was maintained more stable gait by adding proper the load of %BW. It showed Mean 75.03±7.47deg. of supporting①, 70.43±4.89 deg. of airphase, 69.41±3.61 deg. of touchdown and 70.11±4.09 deg. of supporting② and the order of touchdown>supporting②>supporting① in forward tilting angle of trunk in all loads of %BW. It was assumed that more range of flexion in touchdown was due to the trunk flexion in the course of forward acceleration after completion of airphase. Forward flexion of trunk was influenced according to loads of %BW. Right-left lateral tilting of trunk in all loads of BW% didn't show significant difference and maintained more stable gait in x-axis.

CONCLUSION:

The study was to verify the possibility applicable for exercise theraphy of underwater by investigation of exercise effect on the basis of result of kinematic analysis according to the loads of %BW of SCUBA apparatus loaded in underwater activities. The experimental method was based on 3D cinematography analysis on repeative gaits(3 times) according to the load of %BW of SCUBA apparatus with very skilled diver in underwater activities in pool of 5m underwater depth(25m X 25m X 5m). The more the load of %BW, the shorter total elapsed time in all loads. The more the load of %BW, the longer COG displacement(Y) and also the more the load of %BW, the faster COG velocity(Y). Flexion & extension of lower extremities during airphase was performed on the condition of the more the load of %BW, the more flexion in the knee & hip joint but irregular in the ankle joint. It was assumed that it was maintained more stable gait by adding proper the load of %BW when considering fact that the more the load of %BW, the faster flexion in knee & hip angular velocity during airphase. The more the load of %BW, the less forward tilting angle of trunk and also maintained regular posture without changing in right-left lateral tilting angle during 1 stride gait the above results. In conclusion from the above, when the more the load of %BW, there was the shorter elapsed time, the longer COG displacement, the faster COG velocity, the larger range of flexion & extension of lower extremities, the less range of forward tilting of trunk. This is, It was thought that the increase of the load of %BW counteracted the effect of buoyancy and therefore could result in more stable gait. Therefore It could be concluded that improvement of exercise effect of underwater could be elevated by proper application the relationship of resistance & propulsion and have positive effect of exercise therapy by the more the load of %BW in condition submerged of whole body.

REFERENCES:

Chung, Chul-Soo ・ Yoon, Te-Joo ・ Yeon, Yeon-Joo ・ Choi, Chi-Sun(2004). Analysis of kinematics and EMG on stepping over obstacles in elderly persons. *The Korean Journal of Physical Education, 43(5), 423-436.*

Eun, Seon-Deok(2006). An investigation of the effect of the height of steps on the joint moment of lower extremities of the elderly while walking downstairs*. Korean Journal of Sport Biomechanics, 16(4), 31-38.*

Ju, Sung-Bum ・ Park, Gi-Duck ・ Han, Seung-Wan(2005). Effect of aquatic-walking program on body composition and serum lipid and lipoportein in obesity women*. Korea Sport Research, 16(4), 645-652*.

Kim, Moo-Young(2003). A kinematic analysis of gait pattern between the normal men and the lower limb handicapped. *Korean Journal of Sport Biomechanics, 13(3), 163-180.*

Kim, Hyeon-Ju ・ Choi, Jong-Hwan(2006). Effects of 12-week aquatic exercise on the isokinetic muscular function of knee joint in the elderly wome*n. Korean Journal of Physical Education, 45(1), 655-664.*

Kim, Ro-Bin ・ Jin, Young-Wan ・ Moon, Gon-Sung(2005). The influence of step length at different walking speed on the moment of the lower limb joint*. Korean Journal of Sport Biomechanics, 15(2), 93-102.*

Kwon, Y. H.(2004). KWON3D. Motion Analysis Package Ver 3.1.

Plagenhoef, S. C., Evans, F. G., & Abdelnour, T.(1983). Anatomical data for analyzing human motion. *Research quarterly for Exercise and Sport, 54(2), 169-178.*

Ryew, Che-Cheong ・ Kim, Jin-Hyun(2007). Kinematic analysis of gait pattern according to subsidiaries' weight loaded in SCUBA diving. *The Korean Journal of Physical Education, 46(4), 475-484.*

Yoon, Suk-Hoon(2007). The effects of a 24-week walking exercise on obstacle negotiation in older women. *The Korean Journal of Physical Education, 46(4), 485-493.*

Shin, Je-Min ・ Jin, Young-Wan(2006). The kinematic comparison of energy walking and normal working. *Korean Journal of Sport Biomechanics, 16(4), 61-71.*