

GAIT ANALYSIS ACCORDING TO LOADS OF %BW WITH SCUBA DIVING APPARATUS

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The purpose of this study was to present available materials for optimal load of %BW related with underwater activity according to increase of loads of %BW during locomotion in SCUBA diving. A subject participated in the experiment was a skilled male in SCUBA diving(experienced about 1,000 times) and the gaits in every loads of %BW were cinematographed by two cameras for 3D analysis in gymnasium. The results obtained from analysis were as follows; There was significant difference in all variables by elapsing phase-by-phase during gaiting equipped with various loads of %BW and the particularly significant difference was classified into two categories between lighter load of %BW(Load of 0%BW-10%BW) and heavier load(load of 25%BW-40%BW). Therefore the optimal load of %BW moveable easily in rough diving field with SCUBA apparatus was proved to be load of 20-25%BW.

KEY WORDS: scuba diving, gait, optimal load

INTRODUCTION:

Representative human gait on the locomotion was performed by the effect of interaction & functional coordination among joints of lower extremities by means of combined mechanism of neuromusculoskeletal system(Winter,1990). Fundamental human gait cycle in a forward direction consists of repetitive supporting and swing phase.

The preceded studies on the gait had investigated on the subject of normal · abnormal patients of lower extremities, a pregnant, backpack-loaded worker, an obesity, athletes and shoes' heel height etc. from infant to old age. Their topic of the studies consisted of efficiency, velocity of COG, gait posture according to change of %load, and concentrated on running pattern(Morgan etal, 1984), ages(Daniels etal, 1978), training amount(Conley etal, 1988), shoes' weight(Frederick etal, 1984), fluid resistance(Daniel etal, 1985), ground rough degree, shoes' weight(Kwak, 2003).

Also the preceded studies loaded by each body parts were as follows; on hand(Auble etal.,1987), (Graves etal.,1987), Lower extremity(Burse etal.,1979), hand+foot+head(Soule etal.,1969) and weighted shoes(Kwak,2003). Those studies were performed on centering factors influencing normal gait and performed on efficiency · kinematic analysis according to the loads of %BW on an each parts of body.

Recently the concerns to locomotion have specifically been increased in such various underwater activities as underwater leisure activities, various underwater industries, underwater rehabilitation, prevention of injuries, and work efficiency. Equipments necessary in the underwater activities consist of suits, weight, air tanks, various gage consoles, fins, and etc. subsidiaries, and in certain situation divers have to move about 10m-100m to the entry point with 25-30kg weight loaded on spine & lumbar parts. In the course of that, there are high possibility of injury from an unbalanced gait because of the rough surfaces of the ground.

Therefore It was necessary to present the basic materials on optimal gait through the kinematic analysis · comparison and also eradicate optimal load of %BW in a situation of load on each body parts of SCUBA apparatus in gait under gravity.

METHOD:

The subject participated was a male diver experienced about 1,000 times in various diving points and performed 3 repetitive gait experiments for the same load by each load of %BW. The equipments used for 3D cinematograph analysis were consisted of digital cam coder 2ea(30f/s, VX-2000, Sony), a control point box for DLT(Directi Llinear Transformation, 2m x 2m x 1m, Visol.), LED(8555, V-Teck), Light(2ea) and Kwon3D Motion Analysis

Package(ver3.016, Visol) for 3D motion analysis. At the first, two 45-degree-angled cameras were installed, filmed control box, after remove the control box, and filmed the subject's gait motions with every loads of %BW in gymnasium. The film speed was 60 field/sec and exposure time was 1/600sec. The subject's 21 body joints were attached with reflex markers for easy digitization and performed every 3times per a gait on the each load of %BW within control point box

Direction was set to forward(y-axis), lateral(x-axis), and vertical(z-axis) along the gait progression. Analysis model was defined as a body with total 21 joint with 17 segments and used the body segment parameters of Plagenhoef, S. C. etc.(1983). A kind of load 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 of phases · events was classified into 4 phases and 5 events during 1 stride of right leg ; supporting① swing, stance, supporting② of 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, interpolation(0.01sec) used 3rd spline function on the basis of an extracted pair of 2D coordination as a result of digitization using Kwon3D motion analysis program(Kwon, 2004). The error from noise was smoothed(6Hz) using low-pass filter of Butterworth. Calculated data from the 3D coordination consisting temporal, linear kinematic, and angular kinematic variables were normalized by each phases.

RESULT AND DISCUSSION:

Mean±SD of all kinematic variables analysed by gait phases during 1 cycle with loads of %BW of SCUBA apparatus on the ground 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: It was shown that the gait with the increasing load of %BW was more delayed in elapsed time of the study than that of similar result of the slow gait velocity of Shin etc.'s(2006) ratio of 48-60% of supporting phase as total mean 56.46% of supporting phase② and mean 31.52% of supporting phase in all loads of %BW of this study.

Table 1 Mean±SD of temporal, linear & angular variables by gait phases in all loads of %BW of SCUBA apparatus in ground gait

Phases		Supporting-1	Air-phase	Touch-down	Supporting-2
Elapsed time (sec,%)		.33±.08 (31.52)	.36±.13 (34.34)	.08±.00 (7.78)	.28±.05 (26.46)
COG disp.(Y) (cm)		-17.82±10.97	23.65±13.17	52.67±5.53	78.05±11.88
Velocity(Y) (cm/sec)		100.09±23.20	122.34±15.97	144.33±14.49	137.24±13.58
Ang. Disp. (deg)	Hip	166.2±3.8	151.5±10.6	152.0±6.2	163.74±8.4
	Knee	163.9±9.8	134.5±19.9	166.7±12.2	166.25±5.5
	Ankle	107.5±12.7	115.5±9.2	113.8±3.0	104.6±5.2
Ang. Vel. (deg./sec)	Hip	15.16±60.78	-61.11±93.16	-71.67±30.48	54.96±47.65
	Knee	-98.13±134.99	94.69±225.38	-65.51±29.73	32.96±57.38
	ankle	103.04±106.60	-50.24±117.99	-44.47±35.96	-35.91±63.39
Forward tilting of trunk (deg.)		78.5±6.2	80.4±1.4	82.5±0.5	83.1±0.6
Right-left lateral tilting of trunk (deg.)		91.1±1.0	91.4±0.5	90.2±0.2	89.7±0.7

Linear Kinematics: Loads of 0%BW showed longer COG displacement to forward(Y) by 7,68cm than that of mean 76.54cm in case of added loads of %BW as mean 78.05cm in loads of %BW. This result was due to longer difference of COG displacement than mean 50.30cm in case of added load of %BW rather than mean 59.77cm of load of 0%BW in

touch-down. That is, COG displacement moved at the same time to forward direction at the beginning of touchdown just after completion of airphase in load of 0%BW, while delayed more in case of the abnormal gait than those of lower extremities. The result showed a difference between normal and abnormal gait when considering each 55.1cm and 72.6cm of COG displacement in abnormal and normal gait(Kim, Moo-Young, 2003), but no difference among normal gait.

In velocity of COG(Y-axis), It showed significant difference in all phase according to increase of loads of %BW. That is, It was classified into two categories between lighter load of 0%BW · 10%BW and more heavier load of 25%BW · 40%BW in supporting①, airphase and touchdown phase.

When considering influence of COG velocity, It could result in abnormal gait in case of 25% more load of %BW than less loading of %BW when considering load classified largely into light load of 25%BW and heavy load of 40%BW influencing to COG velocity.

Therefore it could assume to generate the higher abnormal gait & possibility of injury in the more loaded of 25%BW of SCUBA apparatus.

Angular Kinematics: In the segment's angular displacement of lower extremities, there was a larger flexion in the load of 0%BW and 40%BW than those of load of 10%BW and 25%BW during supporting phase in the hip joint. From the result, we could assumed to be backward tilting of trunk by loaded weight. When considering the above there was a larger flexion in case of more load of %BW in lower extremities, particularly in the load of 25-40%BW according to the progression of gait cycle phase, and this result was due to proportional relationship between the increase of the load of %BW and the segment 's flexion angle of lower extremities.

In segment's angular velocity of lower extremities, It showed fastest dorsal flexion of mean $13.93 \pm 70.05 \text{deg/sec}$ in the foot segment among all the segments showing the order of high value from proximal to distal segment in all kinds of load of %BW in supporting phase. When compared it to the angular velocity according to the increase of the load of %BW, the air phase performed the largest forward propulsion showed angular velocity of lower extremities in the order of $40\%BW > 25\%BW > 10\%BW > 0\%BW$ load in the airphase. Also it was divided into two groups of largely loaded of %BW and non loaded of %BW when considering the order of $40\%BW > 25\%BW > 10\%BW > 0\%BW$ load.

The mean range of forward tilting of trunk was the order of supporting①>air-phase>touchdown>supporting② in all loads of %BW. It showed decreasing tendency in forward tilting angle according to the progression of gait cycle phase and the more load of %BW was, the larger angular displacement of anterior-posterior & lateral of right-left of trunk showed.

CONCLUSION:

For investigation & presentation of data for injury prevention & optimal load related with normal gait in situation of locomotion with various load of %BW with SCUBA apparatus in ground gait, the study was undertaken to compare & analyse 3D cinematography of gait according to load increase of %BW with SCUBA apparatus on a skilled male diver. Considering the above results of temporal, linear & angular variables, the total elapsed mean time was 1.07sec. and was the more delayed, the more load of %BW in order the airphase>supporting①>supporting②>touchdown. , COG displacement moved at the same time to forward direction at the beginning of touchdown just after completion of airphase in load of 0%BW, while delayed more in case of the abnormal gait than those of lower extremities. That is, Load of %BW influencing to the COG velocity classified into two category between lighter load(0%BW~10%BW) and heavier load(25%BW~40%BW). Therefore optimal load of %BW moveable easily in rough diving field was proved to be load of 20~25%BW. For further reliable & detail conclusions, It was necessary to suggest results of comparison & analysis of 3D cinematography connected with a change of ground reaction force of CG in the same experiment situation.

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