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Design and production of practical underwear for sensing body knowledge ~ Posture control during walking induced by tactile information (Pilot study)

身体知を引き出すアンダーウェアの開発ー触覚が引き出す姿勢制御

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We studied modification of posture by somatosensory input and mechanical support via wearing clothes. We have developed special underwear for upper body having different small cloth patches, which are slightly difficult to be extended, around shoulders and investigated postural changes with motion analysis, some cardio-ventilatory parameters at quiet standing and walking at three different speeds with (WP) and without (WOT) wearing it. Three different walking speed levels were selected at 1, 3, and 7 km/h. Both walks at the slowest and the fastest speeds let subjects respond to disturbances, that is, subjects had to keep attention on body balance. During quiet standing and walking at three speeds, promoted adduction of scapula observed for all three male subjects in WP facilitated efficient ventilation, decreased heat rates, raised center of gravity in body, and widened gaits. We should promote health sciences studying appropriate methods to induce proprioceptive cues working in standing human body under the gravity

1. Introduction

The human being has evolved as a system to automatically produce movement and activities simultaneously to respond outer environment similar to other animals. Various reflexes through neuromuscular connection realize most of the physical activities, and spontaneous ordinary activities are proceeded. However, is it enough to consider only such automatic activities for the human being? Many problems related to body and mind, and loss of the interaction is increasing by westernized life style after the last war, such as life-related diseases, falling down, dementia and so on. The human being is not only as a biological organism consisting of cell system but also potentially involve serious characteristic problem, which are produced by man-made culture through using language and some extraction logic, such as artificial intelligence. Historically, skill of wearing Kimono/Hakama and/or Tatami living style let Japanese people acquire proper posture and body-mind relation naturally and they seems to contributed for both physical and metal health but unfortunately those good customs are completely lost in our modern metropolitan life style.

In the present study, getting a hint from the ancestral treasure of Japanese culture, we have tried to produce an underwear, designed to stimulate fine touching on skin directly, and show some interesting data such as good changes of posture, respiration, and walking pattern as a pilot study.

2. Standpoint of Human Body in Modern Era

2-1. Bipedal walk and keeping upright upper body: Keeping standing position in daily life and bipedal walking and running with maintaining upper body straight upwards may contribute to evolution of homo sapience/human beings from monkey. Through these anti-gravitational activities we have created human culture in enriched environment. However we cannot maintain upright posture by only reflex but conscious motion and effort. We can find signs here a necessity to connect body and mind.

2-2.Decreased physical activities and increased desk work: unhealthy life with hypokinetic diseases with mental diseases despite longevity in Japan, which we have to change happy life.

2-3.**Anti-gravitational control of own posture and body-mind relation**: Balance control is essential for our life on the earth, where cells were born under theory workable in activity-dependent.

2-4.**Cell properties in our human body with softness and elasticity**: human body is consisted of sort materials of proteins. Cells also express various channels and receptors, which works under activity-dependent fashion. Wearing materials with stretchable materials stimulates our body via mechanical stimuli. This increases physical activity dependent.

2-4. **Cutaneous continuity of human body and elasticity**: Our body is consisted of about 400 bones and 1000 skeletal muscles. They are connected with tendons and fascia of

ECM (extracellular matrix), which contains proprioceptive receptors sensing length-tension with ascending feedback neural loop. Our tactile and smoothing body works and exercises may stimulate continuous responsiveness in our body.

2-5.**Experiment to support upper body with anti-gravitational balance and evaluation of posture guidance**: In the present study we evaluated physiological responses, and analyzed posture at standing, motions during walking using three different walking speeds. The slowest may stimulate balancing ability and the fastest may do protecting ability against fall in the Experiment I (Exp 1). Normal walk was evaluated both at the middle speed and free walk in Experiment 2 (Exp 2).

2-6.**Dynamic guidance of good posture with good mind in ordinary daily life**: We have expected to improve body-mind relation during controlling and balancing through three aspects of our body and mind under the gravity (see Figure).

3. Methods

3-1. Subjects: Three males (42 ± 6 20-54 yrs), who have no problem mobile activities, were participated experiments.

3-2. Design of functional wears (Figure 1)

Underwear has been developed attaching different small cloth patches (WP), which are slightly difficult to be extended, around back both shoulders and forearms (for shirts), and give support areas from lumber sacrum and inside of thigh to hip joint (bottom).

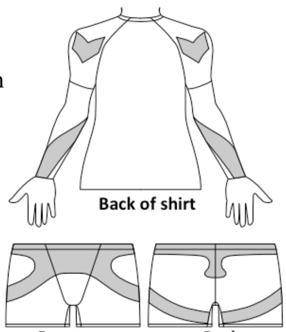

Figure 1 Modification flexibility by patches (WP)

3-3. Experiment 1: Treadmill walking and measurements of cardio-respiratory function and kinematic analysis

(1) Walking exercise at three different speed of 1, 3, and 7 km/h for 3 minutes was performed sequentially associating with at sitting and standing and standing rest before and standing rest after walking (Figure 2).

(2) Respiratory function was measured by using Inter Reha Inc. Expired Gas Analysis System model Cpex-1 (Exp. 1). Motion Analysis was performed using 3D photo-analysis system: VICON Inc. (MX-F).

(3) Total numbers of markers were 35 points as described in figure 2A. The kinematic data were recorded (35 markers were placed on all subject's body segments; Figure 2) using VICON 460 system (Exp-1). The data were used to calculate body COM using Plug-In-Gait model. Data analysis in Exp-1 was performed for appropriate 3-5 cycles of steps during each 3 min-walk at each speed.

(4) Angle produced "STERNUP-both shoulders" (θ) was calculated using 3 points described in figure shown by X=Y rectangular coordinates without considering slope at Z axis. Each location in the coordinates was calculated using STERNUP as 0 point.

(5) Heart Rates were measured using bipolar electrodes (Polar Inc, RS800sd).

3-4. Experiment 2: Free walking (5~6 steps cycles) and measurements of stride length and posture of upper body.

(1) Each subject walked in four patterns with WP (three times of only shirt, only pants, and both shirt & pants) and WOT. Each walk consisted of 10 times 7-m round-trip-walk.

(2) Motion Analysis was performed using 3D photo-analysis system: Motion Analysis Inc. Eagle 1. Kinematic analysis Records of stride length, which was succeeded in obtaining correct data of one gate cycle being able to see heal contacts (shown in Figure 8), were randomly selected and supplied for kinematic analyses.

(3) Angle produced "STERNUP-both shoulders" (θ) was calculated in the same way of Exp. 1.

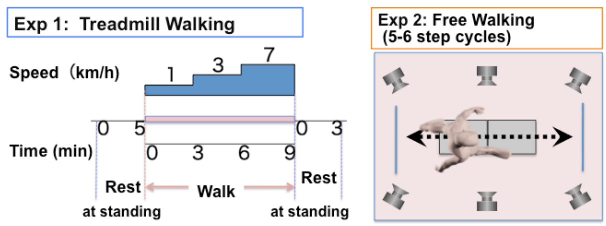

Figure 2 Protocol and design of Exp.1 & Exp.2

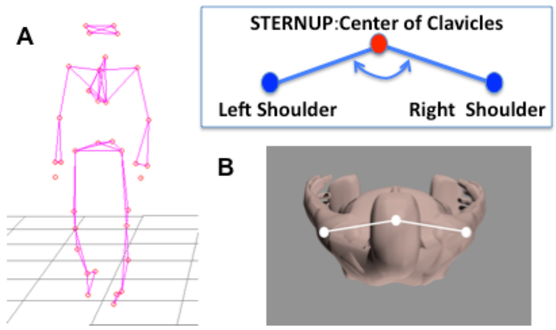

Figure 3 Walking human body with 35 markers (A) and measurement of sternoclavicular joint angle (B).

4. Results

4-1. Treadmill Walking

(1) Improved Efficiency of Respiration with WP

• Cardio-respiratory data performed wearing WP were compared with control condition (WOT; not wearing WP). Mean heart rates at three speeds of three subjects significantly lowered. Respiratory frequencies and ventilatory equivalent (VE/VO2) during walking at three speeds compared with WOT significantly lowered (Figure 4).

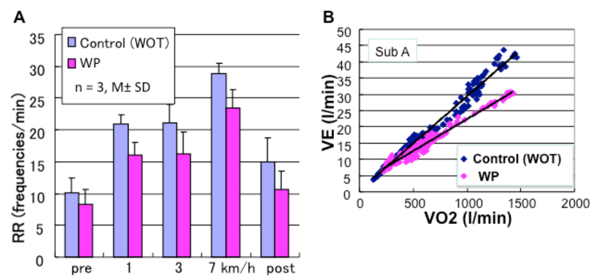

Figure 4 [Exp.1] Comparisons of respiratory frequency (A) and ventiratory equivalent (B at rest, during walking, and at rest for recovery in Sub. A).

(2) Changes of sternoclavicular joint angle (SCJA) with WP

• Change of upper body was partly evaluated as sternoclavicular joint angle (SCJA) during walking at three speeds. Decrease of SCJA was seen at 1km/h walking (Figure 5).

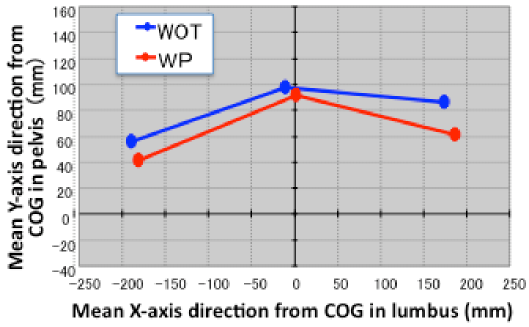

Figure 5 [Exp.1] Decrease of mean sternoclavicular joint angle at 1km/h walking with WP. Mean sternoclavicular joint angle (SCJA) during 3 cycles of walking at 1 km/h for one subject was used. COG: the center of gravity in the human body.

(3) Raised the center of gravity (COG) of body and decreased deviation of COG with WP.

Changes of COG at 1, 3, 7km/h treadmill walking with WP were compared with WOT (Figure 6). COG of wearing WP was higher than those of WOT.

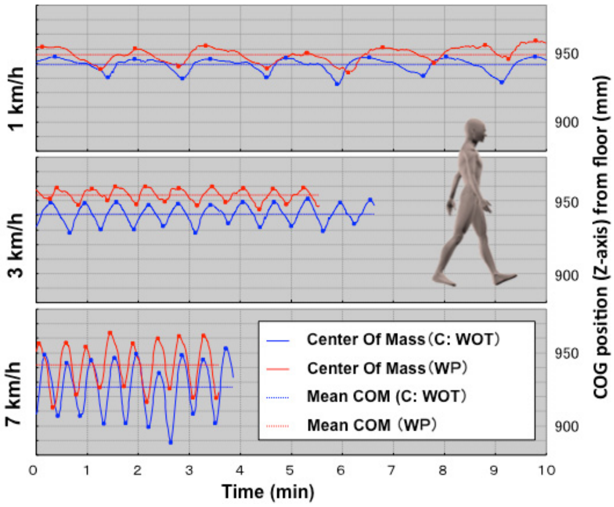

Figure 6 [Exp.1] Comparisons of changes of COG at 1, 3, 7km/h treadmill walking between WP and WOT. (The pattern was almost same among three subjects. A typical example of one subject was shown).

4-2. Free Walking

(1) Changes of sternoclavicular joint angle (SCJA) with WP

• Changes of sternoclavicular joint angle (SCJA) during free walking were measured. Decrease of SCJA (enlargement of the rib cage) and/or balanced angle was observed with WP (Figure 7).

(2) Increased stride with WP

• Changes of height from floor during 1step for 2 subjects. All step width increased with all WP conditions compared with WOT.

Figures 7 shows changes of height from floor during 1step for 2 subjects. All step width (stride) increased with all WP conditions compared with WOT. Significant difference was obtained only in both shirt and pant wearing (Table 1).

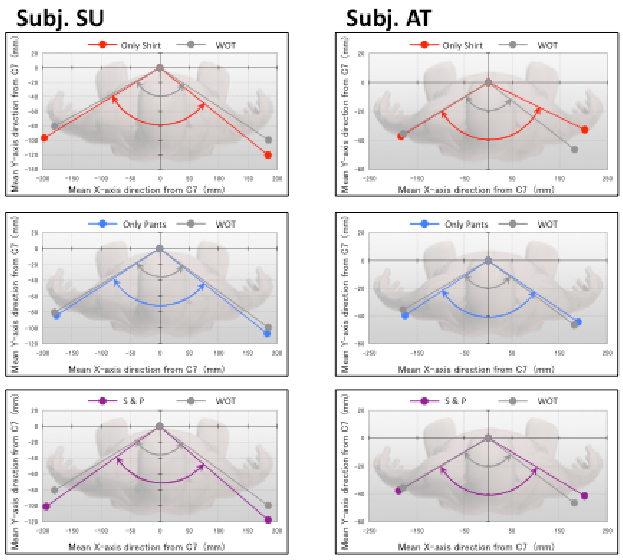

Figure 7 [Exp.2] Decreased or balanced SCJA (enlargement of the rib cage) with WP. Top, middle and bottom figures per each subject show WP-only shirt, pants, and both shirt & pants, compared with control (WOT), respectively.

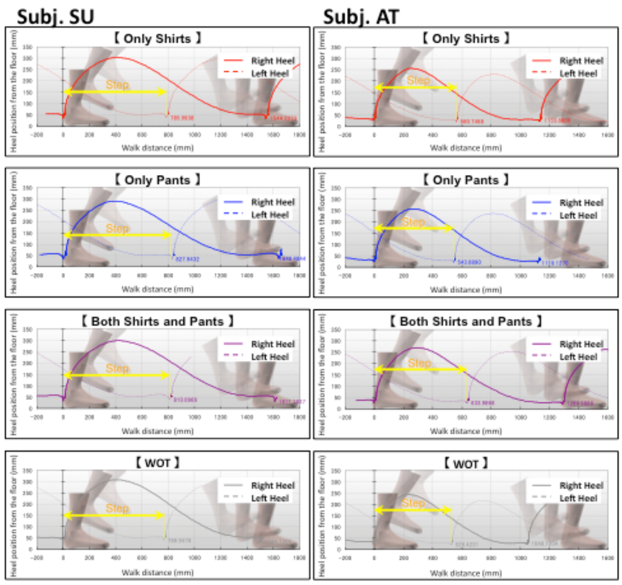

Figure 8 [Exp.2] Changes of height from floor during one step of free walk. One stride was measured by trajectory of one stride from heal contacts.

Table 1 Mean stride and speed during free walking with WP and WOT [Exp.2]

½ Stride	Mean ± SD (cm)
Shirt	69.1 ± 10.1
Punts	68.9 ± 8.5
S&P	73.4 ± 5.1
WOT	67.6 ± 8.1

Speed	Mean ± SD (km/h)
Shirt	4.9 ± 0.7
Punts	4.7 ± 0.7
S&P	5.0* ± 0.6
WOT	4.6 ± 0.8

* p<0.05, (n=4)

5. Discussion

The present pilot study showed a possibility to regulate the posture and walking pattern by wearing fine controlled architecture.

5-1. Regulation of upper body weight via fine-controlled wear and walking human body

The present study showed a possibility that direct wearing of specially controlled underwear, which mechanically stimulates at each cycle of gait over skin around shoulders by the attachment of patches having mild resistance to be stretched, induces improved respiration, posture and gaits in healthy male subjects.

In conclusion, putting on special underwear promoted scapular adduction that supports more thoracic spine extension, resulting in improvement of postural alignment with trunk extension in upright postures. Adduction of scapula directs shoulders backwards and opens chest, resulting in keeping posture. From the results of increased stride of wearing group, we can expect that this wear may contribute to keep people's health against metabolic syndrome. Further precise experiment with increased number of subjects is necessary for elucidating mechanism of the effects of interaction between artificial intelligent wear and dynamic body.

5-2 Possible hypothesis for regulation of standing human body

Considering into posture of human body in space (Figure 9), it is clear that we human being have evolved utilizing the effect of the weight and stand straightly toward vertical direction. Metabolic syndrome increases in modern era and induces various problems of life-relating diseases and fall, health problem like body-mind problem. The weight control of the human body may be considered to regulate from three aspects of upper-lower parts, right-left sides and Front-Back (Dorso-ventral) (Figure 9).

There are three axes to control upright posture of human body, such as upward & downward, front & back, and right & left directions. Human beings became to do basic ordinary activities at standing position, thus we have been to keep upper body weight to be vertical against gravity. Furthermore we also have to control two aspects of right and left brain parts, of which function is different, that is, emotional and analytical. Compared with other four-legs animals, dorso-ventral axis, which means up and down against gravity, of human body changed to the direction of forward and backward. Therefore we humans have to create original method to control upright posture by ourselves.

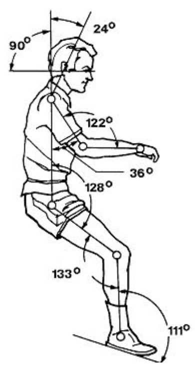

Figure 9. Neutral body posture in the microgravity environment (NASA, Man-Systems Integration Standards, Revision B, July 1995, Volume I, Section 3)

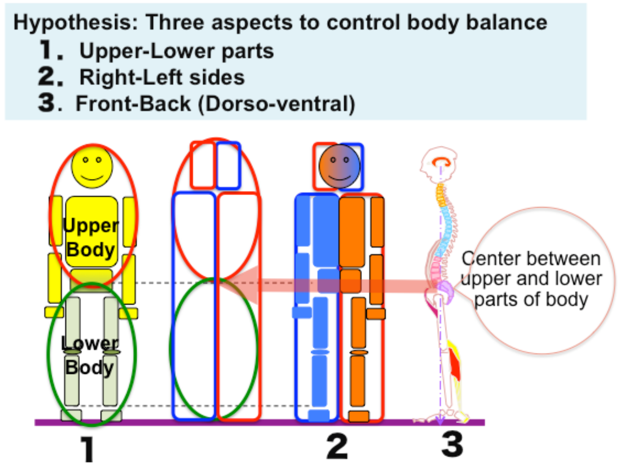

Figure 10 Three aspects to control the human body balance

6. Conclusion and perspective in future

Although the number of subjects in this pilot study is very small, we have gotten some data of field experiment relating to the change of (increased) stride for more than ten subjects for each trial with WP and WOT. Therefore we can continue such a study to elucidate human body mechanism, differentiated from four leg animals, through analysis of wearing finely controlled under this hypothesis.

7. References

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