International Journal of Advanced Smart Convergence Vol.9 No.2 38-48 (2020)
http://dx.doi.org/10.7236/IJASC.2020.9.2.38

IJASC 20-2-5

Effect of Balustrade Heights and Blanket Types on Mechanism of Falling Accident during Shaking-Off the Dust of the Blanket from Balcony

Seunghyun Hyun[1], Checheong Ryew[2†]

[1]*Instructor, Department of Kinesiology, College of Natural Science, Jeju National University, Instructor Republic of Korea*
[2]*Professor, Department of Kinesiology, College of Natural Science, Jeju National University, Professor Republic of Korea*
hshyun0306@jejunu.ac.kr, †ryew@jejunu.ac.kr

Abstract

*The shaking-off the dust from balustrade of higher stories may cause the higher risk of falling accident rate. Main purpose of this study was to quantify an effect of balustrade heights and blanket types on possibility of falling accident relative to one's motor controllability during shaking-off the dust of the blanket from balcony. Female participants, who consisted of total 10 under condition of balustrade height of 3 kinds (90 cm, 110 cm, 130 cm) and blanket types (0.4 kg, 1.6 kg, 3 kg, 200*230 cm), performed repetitively the task of shaking-off the dust of the blanket. Vertical position and velocity of center of mass due to increase of blanket weigh in case of balustrade height of 90 cm was increased, but vertical ground reaction force was decreased swiftly. That is, the higher balustrade height was, the less distance difference between center of mass and center of pressure was.*

Keywords: *Shaking-Off Blanket, Balcony, Whole Body Torque, Balustrade Height, Falling Accident, Death*

1. Introduction

Falling accident is 3rd main source related with death in a household of not only urban [1], but also advanced nation [2] despite installation of safety rail and protection frame of window by the Building Standards Act.

Care & keeping of blanket in household by laundry was deposited by dry laundry, vacuum package etc. depending on its purpose, but management of drying & shaking-off the dust by sunlight on balustrade was also ordinary. But shaking-off the blanket on higher floor may cause mortality to one's lives. Accident by falling had been occurred continuously even though balustrade height of 90 cm-100 cm in private house or apartment had been installed for prevention of falling accident. The aim of this study was to obtain basic material for mechanism which falling accident may occur during shaking-off the dust.

Irregular position & velocity of center of mass (CM) centering on base of support (BOS) of human may

Manuscript Received: March. 21, 2020 / Revised: March. 24, 2020 / Accepted: March. 28, 2020
Corresponding Author: ryew@jejunu.ac.kr
Tel: +82-64-754-3588
Professor, Dept. of Kinesiology Jeju National University, Korea

influence on the risk of falling accident [3]. Capability maintaining and recovering the CM & trunk controllability from instability is very critical for preventing falling accident & injury related with falling accident [4]. Vestibular system receives information through otolith organ which can perceive the direction of head relative to gravity [5]. Determining the direction of vertical gravity may be difficult task when the head is moving or in condition of high frequency [6, 7]. It is not difficult for human to control the balance in the course of carrying blanket with biped locomotion on ground, but rather may be disordered in balancing controllability due to larger movement of body appearing during shaking–off the blanket at the fixed biped

Human mobilizes intentionally movement of one's upper trunk extremity including trunk, arm, head etc. together when maintaining balance of body [8-10]. Body segment connected together even though in case of very complicated external mechanical perturbation during dynamic movement may be controlled by dynamic postural control system [11, 12]. Also in the other study, human may prevent falling accident by counterbalancing the angular momentum against forwarding direction when encountered an obstacles during locomotion. Then angular momentum may be reduced by generation & control of moment of inertia by displacing at more front position the lower extremities than that of CM position in case of enough time & placidity of mind [13, 14].

Another recovery strategy is to depend on the safety rail or near supporting stand [15]. But when considering posture of shaking-off the dust in leaning position against rail of balcony, utility of the posture recovery strategy presented earlier may be impossible. Therefore quantification on mechanism of falling accident in condition of both at posture of fixed biped and for strategy of posture recovery for maintenance of balance is necessary.

Therefore for solution of the above problems, it is necessary to investigate the effect of balustrade heights and blanket types on mechanism of falling accident during shaking-off the dust of the blanket from balcony. Assumptions for this are as follows; the assumption 1st: vertical projection area of CM will not position within center of pressure (COP) range. The assumption 2nd: The higher the balustrade height is, the more reduction rate of body weight is. The assumption 3rd: increase of blanket weight will be influence on the magnitude of whole body torque.

2. Material & Methods

2.1 Subjects

Healthy female (n=10) (age: 21±0.94 years, Height: 1.60±0.06 m, Weight: 59.51±6.62 kg) of 20s participated in the experiment, of whom excluded the disorder with visual disturbance, muscular skeletal impairment, dislocation of shoulder joint, arthritis, and balance hindrance. This study was approved by Jeju National University Institutional Review Board (Protocol Number: JJNU-IRB-2018-057) and all participants signed on prior a written consent voluntarily.

2.2 Experimental approach

All participants recorded her standing height and body weight prior to experiment and wore upper and lower tights of black color type with bare foot. Reflex markers for securement kinematic data were attached on head (3 markers), trunk (4 markers), upper extremities (14 markers), and lower extremities (22 markers) (Figure 1).

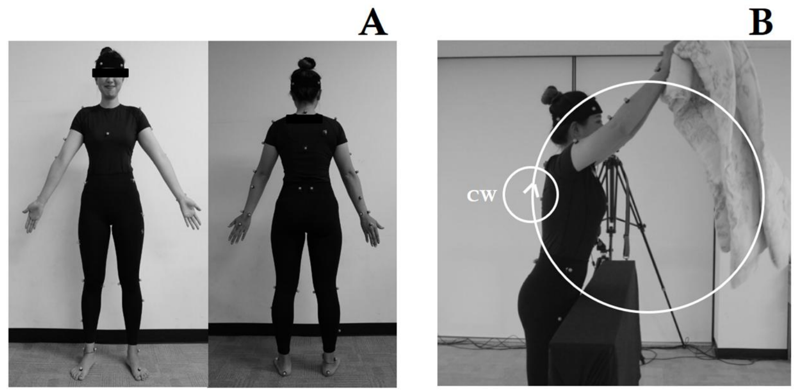


Figure 1. Anatomical posture and reflex marker attachment (A), Torque direction of whole body (B)

The reflex marker were captured by 12 motion capture camera (Vicon MX Giganet) at frequency of 100 Hz and were transferred into digital signal and then were saved on software program (Nexus, Vicon Motion System Ltd., UK). Balcony fabricated with wooden box was standardized 1 m (height 1 m*width 2 m*depth 1.5 m) from ground level and rectangular balustrade (width 2 m*length 0.8 m* width 0.2 m, weight 100 kg) on balcony was adjusted to each experimental height. Balustrade height was adjusted to 130 cm and 110 cm on the basis of 90 cm (normalized ratio to body height 56.10%, 68.57%, 81.04%) by the Building Standards Act to maintain consistency and to prevent a falling accident. Blanket weight of 0.4 kg, 1.6 kg, and 3 kg (normalized ratio of body weight 0.67%, 2.71%, 5.09%) and size of 200*230 cm using commonly in daily life was standardized to experimental condition respectively.

Wooden box designed for balcony was fixed firmly, and 2 force plate (AMTI-OR-7, Advanced Mechanical Technology Inc., Watertown, MA, USA) set up at frequency of 1,000 Hz was installed on balcony. Cinematographic data for analysis were measured repetitively maximal 3 times for 1 movement and were consisted of total 9 movements per every one participant. In case of transfer error of ground reaction force (GRF) data and failure of camera-attachment marker, repetitive measurement was performed after enough rest. Researcher urged all participants to make utmost efforts against task of shaking-off the dust and laid mattress around balcony to prevent injury from falling accident.

2.3 Event analysis

Whole body modeling of movement used to investigate mechanism of falling accident from balustrade was monitored and quantified. Normalization was done for analysis by events of each individual using modeling generated from VICON during shaking-off the dust. Only movement of events of #2, #3, #4 for specialized 5 movements were utilized for analysis, and movement of events of #1, #5 were for description of events.

- Event 1: ready posture in a state of grasped blanket by both hands extended forward maximally in stable posture after toe- touch against balustrade.

- Event 2: elevated state maximally of both hands for shaking–off the dust.

- Event 3: Most reduced posture in vertical GRF against both foot after shaking-off the dust.

- Event 4: Most heightened posture in vertical GRF in a state of lowest position of both hands.

- Event 5: Vertical GRF data after completion of shaking-off the dust of 1 times, corresponding posture at point which represents the same value as that of ready posture.

Phase, Phase 1 : Event 1-Event 2, Phase 2 : Event2-Event 3, Phase 3 : Event 3-Event 4, Phase 4: Event 4-Event 5

According to the above events, variables of CM position against vertical direction, change of acceleration, inclined angle of trunk, vertical GRF, and torque of whole body to investigate mechanism of falling accident were calculated.

2.4 Data processing

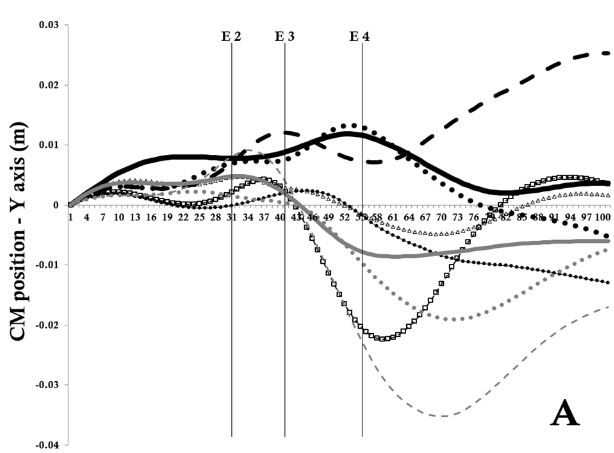
Whole body torque was viewed from sagittal plane difference between CM and vertically projected anterior-posterior axis of COP obtained from GRF data. Then CW torque means positive (+) and CCW torque means negative (-).

Repetitive Two-way ANOVA (SPSS, IBM, Armonk, NY, USA) was utilized for statistical significance test on analysis variables under condition of balustrade (90 cm, 110 cm, and 130 cm) and blanket types (0.4 kg, 1.6 kg, and 3 kg) ($P<0.05$).

3. Results

3.1 Kinematics of CM

In the Figure 2, balustrade height of 90 cm (0.005 m) showed longer displacement forward than that of 110 (0.004 m) and 130 cm (-0.0006 m) at phase 2 ($p=0.17$, F=4.279), but showed shorter displacement backward at phase 3 ($p=0.005$, F=5.617) in analysis of main effects of balustrade height in position change of CM in anterior-posterior direction. While blanket size of L (-0.01 m) showed more backward displacement than that of M (-0.008 m) and S (-0.009 m) in main effects of blanket weight at phase 3 (p =0.006, F=5.529). Height of 90 cm (-0.03 m) showed more vertical downward displacement than that of 110 (-0.02 m) and 130 cm (-0.01 m) in main effects of balustrade height on vertical displacement of CM at phase 3 (p =0.001, F=11.900). Type of L (-0.016 m, -0.029 m) showed more downward displacement than that of M (-0.015 m, -0.021 m) and S (-0.009 m, -0.022 m) in main effects of blanket types at phase 2 ($p=0.005$, F=5.687) and phase 3 ($p=0.037$, F=3.431).



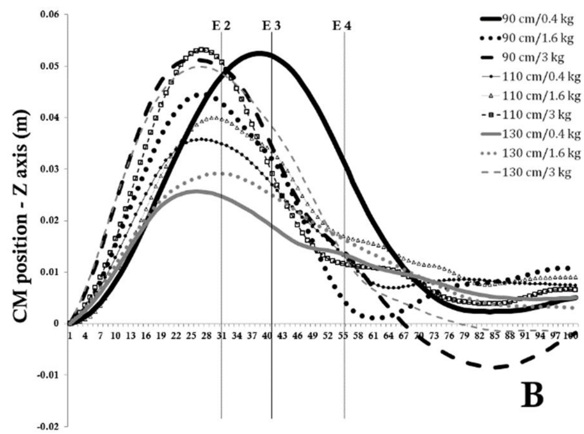


Figure 2. Chance of COM position (A, B)

Height of 90 cm (0.42 m/s^2) showed faster value than that of 110 m (0.26 m/s^2) and 130 cm (-0.1 m/s^2) in main effects of balustrade height on anterior-posterior acceleration of CM at phase 2 (p=0.02, F=4.119). Types of L (-1.23 m/s^2) showed faster value than that of M (-0.94 m/s^2) and S (-0.79 m/s^2) in main effect of blanket types at phase 3 (p=0.036, F=3.460). Height of 90 cm (1.16 m/s^2, 2.49 m/s^2) showed faster value than that of 110 m (-0.92 m/s^2, 2.14 m/s^2) and 130 cm (-1.02 m/s^2, 1.23 m/s^2) in main effects of balustrade height on vertical acceleration of CM at phase 3 (p=0.001, F=9.221) and phase 4 (p=0.021, F=4.059). Types of L (2.20 m/s^2) showed faster value than that of M (2.14 m/s^2) and S (1.23 m/s^2) in main effects of blanket types at phase 4 (p=0.030, F=3.666). Interaction between position change of CM and change of acceleration on balustrade height and blanket did not show (Figure 3).

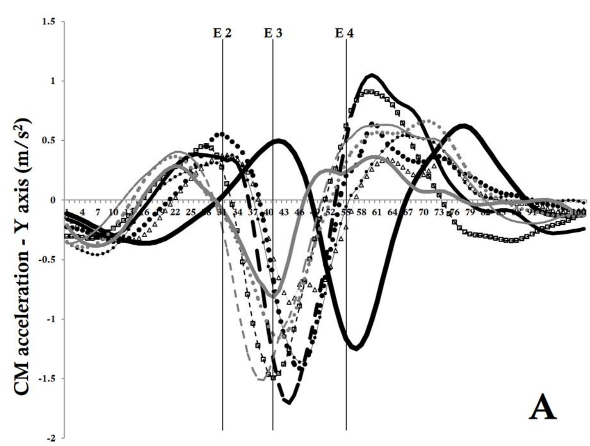


Figure 3. Chance of COM acceleration (A, B)

3.2 Trajectory of CM-COP

Difference of displacement in anterior-posterior direction between CM and COP in horizontal plane was quantified. Balustrade height of 90 cm (1.6 kg, 3kg) and110 cm (3 kg) influenced on the forward displacement. In the course of shaking-off the blanket. Interaction between balustrade height and blanket types on difference of CM-COP did not show (Figure 4).

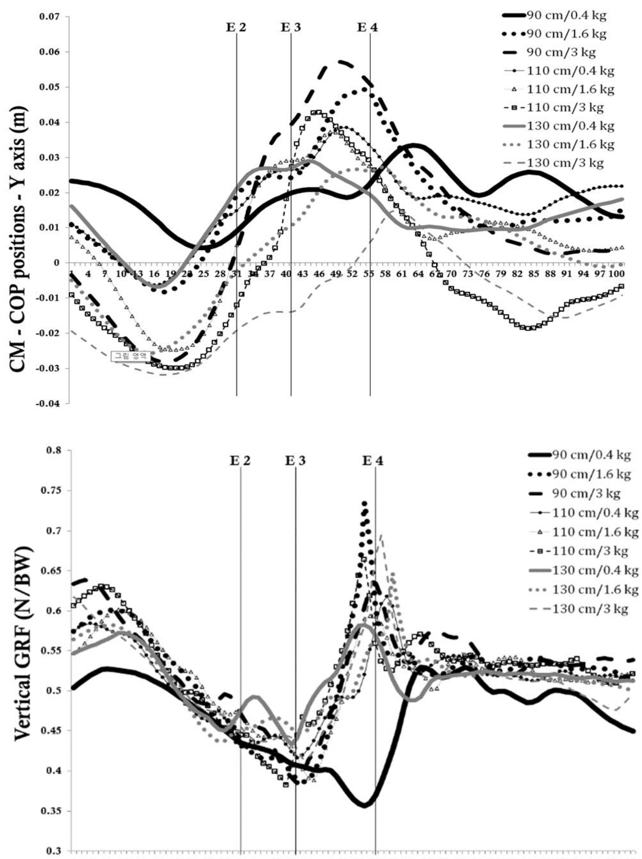


Figure 4. Displacement difference between COM and COP relative to balustrade height and blanket types and change of vertical GRF

3.3 Vertical GRF

Height of 90 cm (0.37 N/BW) showed less supporting value of weight than that of 110 (0.39 N/BW) and130 cm (0.0.42 N/BW). In main effects of balustrade height on vertical GRF at phase 3 (p=0.001, F=7.769). Type of L (0.66 N/BW) showed more supporting value of weight than that of M (0.66 N/BW) and S (0.57 N/BW) in main effects of blanket types at phase 4 (p=0.038, F=3.401). Interaction between balustrade height and blanket types on vertical GRF did not show (Figure 4).

3.4 Inclined angle of trunk and torque of whole body

Main effect of balustrade height on inclined angle of trunk through all event showed statistical significant difference. Height of 90 cm (-4.31 deg.) showed less backward inclined angle of trunk than that of 110 m (-7.68 deg.) and 130 cm (-11.07 deg.) at event 2 (p=0.001, F=10.973). Height of 90 cm (2.69 deg., 6.50 deg.) showed more increased forward inclined angle of trunk than that of 110 m (-1.56 deg., 1.29 deg.) and 130 m (-1.74 deg., -7.45 deg.) during shaking-off blanket at event 3 (p=0.001, F=150.932) and event 4 (p=0.001, F=17.252). Type of L (-9.99 deg.) showed more increased forward inclined angle of trunk than that of M (-7.25 deg.) and S (-5.83 deg.) in main effects of blanket types at event 2 (p=0.017, F=4.299).

Heights of 90 cm (-48.87 N-m) and 110 cm (-49.25 N-m) showed more increased backward torque than that of 130 cm (-34.90 N-m) in main effect of balustrade height on torque of whole body at event 2 (p=0.023, F=3.973). while height of 90 cm (32.14 N-m) and110 cm (31.27 N-m) showed more increased forward torque of trunk than that of 130 cm (7.78 N-m) during shaking-off blanket at event 4 (p=0.002, F=6.667). Interaction between balustrade height and blanket types on inclined angle of trunk and torque of whole body did not show.

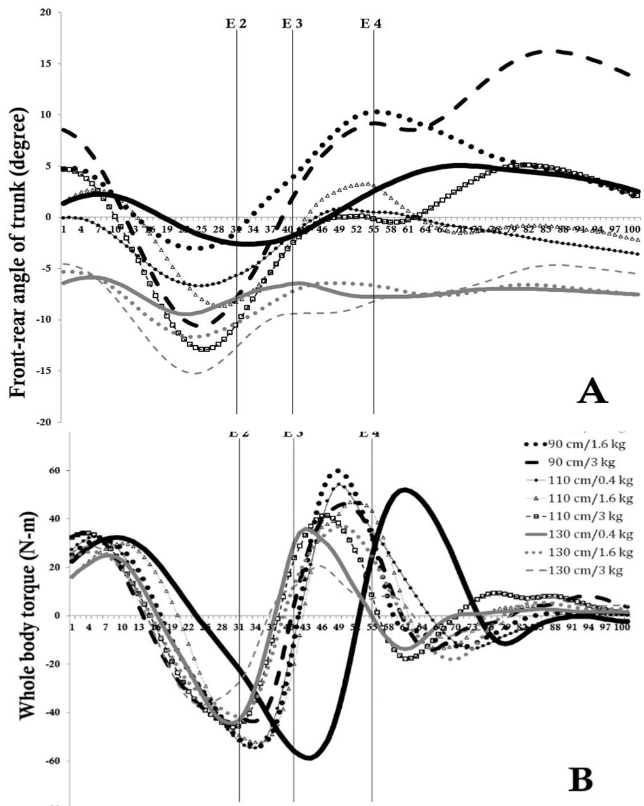


Figure 5. Definition of inclined angle of trunk (A) and torque of whole body (B)

3.4 Interview result

Table 1 shows interviewed contents after survey. And interview contents with participants when experiment was completed were as follows; 1) Event falling accident was happened ?, 2) Controlling ability of whole body in case of if falling accident was happened ?

Table 1. Interviewed contents with participants (n=10)

Phase which was felt falling may happen ?	Possibility controllable a balance when be felt fall may happen ?
S 1. When shaking-off in lowered balustrade height	Required wrist snap and arm strength
S 2. An instant raising and lowering of blanket	Required strength of wrist and shoulder joint
S 3. Just before of lowering after raised of blanket	Disability of controllability
S 4. Just moment lowering a blanket	Keeping one's balance by leaning trunk against balustrade or standing with toe
S 5. A point leaning outward balustrade when shaking-off the blanket	Required balance and muscle strength
S 6. Feeling leaning of trunk when reacted after shaking-off the blanket	By Positioning backward of COM of trunk
S 7. Because of reaction after shaking –off the blanket	By maintaining COM backward of balustrade
S 8. When shaking-off the blanket	By leaning elbow joint on balustrade
S 9. When dropping downward both arm powerfully	By leaning elbow joint on balustrade

S 10. When dropping to lower position from the above position By standing with toe of blanket

4. Discussion

This study diversified into variables of balustrade heights and blanket weights to investigate mechanism of falling accident of human. It is desirable not to shake-off the dust on balcony to prevent falling accident, but quantitative data inspirable on an awareness was not yet suggested. This study is tentative study which may prove a potential risk to be occurred suddenly during shaking-off the blanket from balcony. Participants' subjective answers from interviewer was coincided with results of quantitative data obtained from 3D cinematographic & GRF data.

Researcher paid attention to change of position & acceleration of CM to interpret relationship between CM and COP. Vertical projection of CM should be positioned within base of support(BOS) to keep equilibrium in static state [3]. Also BOS was determined by origin point or supporting area of GRF vector [16, 17]. Velocity of CM should be considered for keeping equilibrium, which may fail when CM get out of BOS, but may succeed when get inward of BOS [3]. Shaking off the blanket on balustrade height of 90 cm in this study showed more increased change of position and acceleration of CM than that of 110 cm and 130 cm in anterior-posterior direction. This meant that equilibrium was decreased by lowered CM position due to increase of range of movement (ROM) of body segment when balustrade height was lowered relatively.

Shaking-off the blanket is similar with motion of standing long jump or preliminary swing motion of forward up-down of arms in vertical jump when observed from sagittal plane. Arm utilization during vertical jump was contributed to improvement of jump height over 10% [18-20], and also vertical height and velocity of CM due to arm weight was increased [21]. On the other hand, additional weight loaded on backside of trunk brought about both forward inclined angle of trunk [22]and elevation vertical height of CM of whole body [23]. That is, main purpose of shaking-off the blanket is not jumping, but swing motion of forward up-down of arms may influence partially on elevation of vertical height of CM.

Blanket type of L shifted position of CM more backward than that of M and S during shaking-off the blanket at Event 3. Increased weight of blanket with arm motion for shaking-off the blanket influenced on change and movement of CM position, which is considered to be mechanism for maintenance its equilibrium and controllability. But behavior of shaking-off the blanket in posture grasped blanket and extended arm forward may cause its CM position to disturb, and thus may result in failure of equilibrium restoration.

Like this, whole body torque did not located within range of COP against CM during shaking-off the blanket, thus 1st assumption was satisfied. This assertion can be explained in difference of position between CM and COP, and vertical GRF (Figure 4). Position difference between CM and COP was arrived at maximal value under condition of 90 cm (1.6 kg, 3 kg) and 110 cm (3 kg) at phase 3. Vertical GRF means a degree of body weight supporting during shaking-off the blanket. Because of task performance on GRF by biped which does not exceed 100 % over body weight, it is supporting rate (%) of body weight that should be considered in analysis. Balustrade height of 90 cm and 110 cm showed more decreasing trend in GRF than that of 130 cm. Also the result satisfied 2nd assumption. This is, reduction in rate of body weight may contributed to elevation of CM and increase of falling accident possibility.

Balustrade height of 90cm and 110 more restricted the backward inclined angle than that of 130 cm, but showed the highest forward inclined angle after completion of shaking-off the blanket in inclined angle of trunk. This feature and rotational torque showed highest value at event 2. When considering relation between rate of body weight (%) and CM-COP, it may be assumed that occurrence of falling accident can be prevented by increase of torque against backward rotation, but inertia generated in the course of shanking-off the blanket may be contributed to generation of forward torque. This basis of assertion may be asserted because balustrade height of 90cm and 110cm contribute greatly to generation of forward rotational torque. In addition occurrence of falling accident may be not only very fatal but also increase an injury possibility (%) of vertebrae & muscular skeletal system by flexion of trunk against forward-backward direction and increase of rotational torque [24].

Though there is no analysis on EMG (Electro Myo Graphics) and MRI(Magnetic Resonance Image) on vertebrae column and movement of pelvis in this study, but faulted motor control in level of partial muscular system may brought about inappropriate level of muscle strength and stiffness, and thus may injure stabilization partially [25]. In default of course of readiness, and feed-forward for muscular activation, error width between neuro and muscular function related with vertebral stabilization may be increased [24]. When shaking-off the blanket, it should be considered that suddenly increased great load on vertebral part by air resistance against blanket area without enough warm-up may occur. Therefore it will be necessary to perform a follow-up study related with effect of air resistance against blanket area.

When summarizing the above analysis, event 2-event 3 of maximal vertical point of both hand (Event 2) followed shaking-off blanket (phase 3) for shaking-off the blanket was verified quantitatively to be origin generating rotational inertia of whole body. Also this study assumed that blanket weight will influence on rotational inertia of whole body, but greatly influenced by balustrade height (90 cm > 110 cm >130 cm). Therefore assumption 3rd was satisfied partially. Therefore falling accident may occur frequently during shaking-off the blanket, and furthermore it may be under condition of the old age, troublesome of equilibrium, lowered coefficient of friction between foot and floor, wear of slipper. Therefore variability of falling accident should be considered with variables of age, gender, type of shoe, bottom materials, and coefficient of friction etc. together [26, 27].

5. Conclusion

We found that shaking-off the blanket on balcony may influence greatly the mechanism of falling accident. Higher balustrade height was effective for controllability of position and acceleration of center of mass. First of all, it reduced rotational whole body-torque toward shaking-off the blanket. Increased weight of the blanket (over 2.71%) influenced greatly on torque generation, acceleration of center of mass and change of position, and also balustrade height per standing height (81.4%) reduced falling accident possibility (%). Consequently factor occurrence of falling accident had close relation with rate of the body weight supporting (%) in the course of backward torque of whole body transferring to forward torque generated at downward point after maximal elevation of both hands for shaking–off the dust. Dynamic postural characteristics generated at this point more influenced on occurrence of falling accident than in completion stage of shaking-off the blanket.

Acknowledgement

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2018S1A5B5A07071069)

References

[1] C. A. Musemeche, M. Barthel, C. Cosentino, and M. Reynolds, "Pediatric falls from heights," *The Journal of trauma,* vol. 31, no. 10, pp. 1347-1349, 1991. DOI: https://doi.org/10.1097/00005373-199110000-00004.

[2] B. J. Shields, E. Burkett, and G. A. Smith, "Epidemiology of balcony fall–related injuries, United States, 1990-2006," *The American journal of emergency medicine,* vol. 29, no. 2, pp. 174-180, 2011. DOI: https://doi.org/10.1016/j.ajem.2009.08.023.

[3] A. Hof, M. Gazendam, and W. Sinke, "The condition for dynamic stability," *Journal of biomechanics,* vol. 38, no. 1, pp. 1-8, 2005. DOI: https://doi.org/10.1016/j.jbiomech.2004.03.025.

[4] M. J. Pavol and Y.-C. Pai, "Feedforward adaptations are used to compensate for a potential loss of balance," *Experimental Brain Research,* vol. 145, no. 4, pp. 528-538, 2002. DOI: https://doi.org/10.1007/s00221-002-1143-4.

[5] W. H. Paloski, S. J. Wood, A. H. Feiveson, F. O. Black, E. Y. Hwang, and M. F. Reschke, "Destabilization of human balance control by static and dynamic head tilts," *Gait & posture,* vol. 23, no. 3, pp. 315-323, 2006. DOI: https://doi.org/10.1016/j.gaitpost.2005.04.009.

[6] S. Glasauer, "Linear acceleration perception: frequency dependence of the hilltop illusion," *Acta Oto-Laryngologica,* vol. 115, no. sup520, pp. 37-40, 1995. DOI: https://doi.org/10.3109/00016489509125184.

[7] L. Nashner, "A model describing vestibular detection of body sway motion," *Acta Oto-Laryngologica,* vol. 72, no. 1-6, pp. 429-436, 1971. DOI: https://doi.org/10.3109/00016487109122504.

[8] E. Otten, "Balancing on a narrow ridge: biomechanics and control," *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences,* vol. 354, no. 1385, pp. 869-875, 1999. DOI; https://doi.org/10.1098/rstb.1999.0439.

[9] M. Milosevic, K. M. V. McConville, and K. Masani, "Arm movement improves performance in clinical balance and mobility tests," *Gait & posture,* vol. 33, no. 3, pp. 507-509, 2011. DOI; https://doi.org/10.1016/j.gaitpost.2010.12.005.

[10] A. M. Schärli, R. van de Langenberg, K. Murer, and R. Müller, "Postural control and head stability during natural gaze behaviour in 6-to 12-year-old children," *Experimental brain research,* vol. 227, no. 4, pp. 523-534, 2013. DOI: DOI; https://doi.org/10.1007/s00221-013-3528-y

[11] F. Honegger, R. Tielkens, and J. Allum, "Movement strategies and sensory reweighting in tandem stance: differences between trained tightrope walkers and untrained subjects," *Neuroscience,* vol. 254, pp. 285-300, 2013. DOI:https://doi.org/10.1016/j.neuroscience.2013.09.041.

[12] M. Patel, D. Buckwell, M. Hawken, and A. M. Bronstein, "Does outstretching the arms improve postural stability?," *Neuroscience letters,* vol. 579, pp. 97-100, 2014. DOI: https://doi.org/10.1016/j.neulet.2014.07.010.

[13] M. D. Grabiner, J. W. Feuerbach, and D. W. Jahnigen, "Measures of paraspinal muscle performance do not predict initial trunk kinematics after tripping," *Journal of biomechanics,* vol. 29, no. 6, pp. 735-744, 1996. DOI: https://doi.org/10.1016/0021-9290(95)00142-5.

[14] Y.-C. Ko, C.-C. Ryew, and S.-H. Hyun, "Relationship among the variables of kinematic and tilt angle of whole body according to the foot trip during gait," *Journal of exercise rehabilitation,* vol. 13, no. 1, p. 117, 2017. DOI: https://doi.org/10.12965/jer.1732846.423.

[15] B. E. Maki and W. E. McIlroy, "The role of limb movements in maintaining upright stance: the “change-in-support” strategy," *Physical therapy,* vol. 77, no. 5, pp. 488-507, 1997.DOI: https://doi.org/10.1093/ptj/77.5.488.

[16] A. Shumway-Cook and M. Woollacot, "Motor Control: Theory and Practical Applications, Baltimore, MD: Williams and Wilkins," 1995.

[17] D. Winter, "ABC of Balance during Standing and Walking Waterloo Biomechanics," ed: Waterloo, 1995.

[18] M. E. Feltner, D. J. Fraschetti, and R. J. Crisp, "Upper extremity augmentation of lower extremity kinetics during countermovement vertical jumps," *Journal of sports sciences,* vol. 17, no. 6, pp. 449-466, 1999. DOI: https://doi.org/10.1080/026404199365768.

[19] E. A. Harman, M. T. Rosenstein, P. N. Frykman, and R. M. Rosenstein, "The effects of arms and countermovement on vertical jumping," *Med Sci Sports Exerc,* vol. 22, no. 6, pp. 825-833, 1990. DOI: https://doi.org/10.1249/00005768-199012000-00015

[20] A. B. Shetty and B. R. Etnyre, "Contribution of arm movement to the force components of a maximum vertical jump," *Journal of Orthopaedic & Sports Physical Therapy,* vol. 11, no. 5, pp. 198-201, 1989. DOI: https://www.jospt.org/doi/10.2519/jospt.

[21] K. B. Cheng, C.-H. Wang, H.-C. Chen, C.-D. Wu, and H.-T. Chiu, "The mechanisms that enable arm motion to enhance vertical jump performance—A simulation study," *Journal of biomechanics,* vol. 41, no. 9, pp. 1847-1854, 2008. DOI: https://doi.org/10.1016/j.jbiomech.2008.04.004.

[22] J. J. Knapik, K. L. Reynolds, and E. Harman, "Soldier load carriage: historical, physiological, biomechanical, and medical aspects," *Military medicine,* vol. 169, no. 1, pp. 45-56, 2004. DOI: https://doi.org/10.7205/MILMED.169.1.45.

[23] T. Singh and M. Koh, "Effects of backpack load position on spatiotemporal parameters and trunk forward lean,"

Gait Posture, vol. 29, no. 1, pp. 49-53, Jan 2009. DOI: https://doi.org/10.1016/j.gaitpost.2008.06.006.

[24] R. Preuss and J. Fung, "Can acute low back pain result from segmental spinal buckling during sub-maximal activities? A review of the current literature," *Manual therapy,* vol. 10, no. 1, pp. 14-20, 2005. DOI: https://doi.org/10.1016/j.math.2004.08.006.

[25] S. M. McGill and J. Cholewicki, "Biomechanical basis for stability: an explanation to enhance clinical utility," *Journal of Orthopaedic & Sports Physical Therapy,* vol. 31, no. 2, pp. 96-100, 2001. DOI: https://www.jospt.org/doi/10.2519/jospt.2001.31.2.96.

[26] T. Kwon, J.-Y. Lee, and K.-D. Jung, "Design of Cloud-based Context-aware System Based on Falling Type," *International Journal of Internet, Broadcasting and Communication,* vol. 9, no. 4, pp. 44-50, 2017. DOI: https://doi.org/10.7236/IJIBC.2017.9.4.44.

[27] T. Kwon, D. Lee, J.-Y. Lee, and K.-D. Jung, "Design of Falling Context-aware System based on Notification Service using Location Information and Behavior Data," *International Journal of Internet, Broadcasting and Communication,* vol. 10, no. 3, pp. 42-50, 2018. DOI: https://doi.org/10.7236/IJIBC.2018.10.3.42.