Acta of Bioengineering and Biomechanics
Vol. 12, No. 4, 2010

Original paper

The influence of trunk inclination on muscle activity during sitting on forward inclined seats

ANDRZEJ MASTALERZ[1, 2]*, IWONA PALCZEWSKA[1]

[1] Institute of Industrial Design, Warsaw, Poland.
[2] University of Physical Education in Warsaw, Faculty of Physical Education and Sport, Biała Podlaska, Poland.

The aim of the study was to estimate the influence of trunk inclination on muscle activity during sitting on forward inclined seats without backrest. The group consisting of thirteen healthy women was examined. Based on anthropometrical data two types of sitting position were adopted with two different angles between thighs and trunk: 120 and 135 degrees. Bioelectrical activity of five muscles was recorded. There was observed statistical influence of the trunk inclination on erector spinae, gastrocnemius lat. and tibialis anterior ($p < 0.05$). Especially, the inclination of seat pan influenced tibialis anterior activity (10%), although EMG measured during sitting did not exceed 20% of MVC.

Key words: *ergonomics, biomechanics, EMG, sitting-standing position, unsupported sitting, chair*

1. Introduction

The prolonged low-level static load on the back during sitting can be hypothesized to affect back muscles adversely. HÄGG [1] and WESTGAARD and DeLUCA [2] indicated that prolonged low-level activity of muscle influenced higher muscle activity of other muscle group. Some studies demonstrated associations between a history of sedentary work, low-back pain prevalence and degenerative changes of the intervertebral disc [3], [4]. EKLUND and CORLETT [5] and ALTHOFF et al. [6] described the influence of back rest on spinal shrinkage reduction when using, for instance, a chair with and without back support. Frequent postural changes and more frequent periods of relaxation of parts of the extensor musculature were indicated to prevent back discomfort experienced during prolonged sitting [7]. KROEMER [8], SERBER [9] and SUZUKI et al. [10] proposed the so-called dynamic chairs to prevent low-back pain. However, JENSEN and BENDIX [11], who studied those types of chair, did not find their influence on muscle activity. That theory was supported by van DIEEN et al. [12] who observed that trunk kinematics and erector spinae EMG were strongly affected by the task performed, but not by the chair type. KROEMER and GRANDJEAN [13], SCHOBERTH [14], ZACHARKOW [15], and PHEASANT [16] believed that sitting postures put more load on the spinal discs than standing postures. KIMURA et al. [17] found that biomechanical axial stress for the intervertebral disc increased most at L4–L5 due to a decrease in a disc height in upright posture. More recent in vivo recordings of the intradiscal pressure (IDP) made by WILKE et al. [18] and ROHLMANN et al. [19] show, however, that sitting may produce less intradiscal pressure than standing. PEZOWICZ et al. [20] demonstrates that intradiscal pressure in lower spine is high in comparison to this pressure in top segments and the biggest changes in the pressure occur in bending motion, particularly in flexion. At the beginning of the twentieth century,

* Corresponding author: Andrzej Mastalerz, Institute of Industrial Design, ul. Świętojerska 5/7, 00-236 Warsaw, Poland. E-mail: andrzej_mastalerz@iwp.com.pl
Received: May 22nd, 2010
Accepted for publication: October 18th, 2010

people were taught to sit with their knees and hips forming right angles. Fifty four years ago KEEGAN [21] established the relation between trunk–thigh angle and lumbar spine curvature. Keegan found that the angle of 135 degrees would restore the lordosis and give an optimal lumbar curve. Nearly forty years ago any scientist argued that sitting with right angles is biomechanically incorrect [14], [22]–[26]. LeLONG et al. [27] found that sloping the seat 10° forwards resulted in up to a 30% decrease in intradiscal pressure. At larger forward slopes a greater variability was found, which the authors attributed to increased muscular tension. BENDIX and his colleagues [28], [29] advocated a forward sloping seat with a tilted desk as a means of improving trunk posture. MANDAL [30]–[32] was a principle exponent of steeply forward sloping seats, especially for schools, and chair manufacturers were quick to take up the idea in office furniture. In practice, the most traditional office chairs have a 2–4° backwards slope in the area where the ischial tuberosites rest when the back of the sitter is in contact with the backrest. ANDERSON et al. [33] proposed to open the trunk–thigh angle by increasing the backrest angle. But, the simple information about correct slope selection of the seat and its influence on muscles load during sitting without back support is still necessary. Therefore the aim of the study was to estimate the influence of trunk inclination on muscle activity during sitting without backrest on forward inclined seats.

2. Material and methods

The group of thirteen healthy women, without acute or chronic problems of the muscular-skeletal system (body mass: 68 ± 12 kg, body height: 170 ± 5 cm, age: 22 ± 1 years) took part in examinations. Measurements were done on the specially prepared stand consisting of self-adjustable chair and working table. Based on anthropometric data two types of sitting positions were adopted with two different seatpan heights and the angles responsible for the angles between thighs and vertical line of the trunk: 120 and 135 degrees (called in this paper: 120 deg position and 135 deg position of seatpan slope). The five unsupported trunk inclinations relatively to the perpendicular were applied during sitting at both seatpan positions: –30, –15, 0, 15 and 30 degrees. The subjects were asked to sit for ten seconds with trunk inclined at both seatpan positions. The activities of five muscles were recorded by Octopus EMG (Bortec-Biomedical Ltd): trapezius p. transversus (TR), erector spinae (ES), rectus femoris (RF), gastrocnemius lat. (GL), and tibialis anterior (TA). Surface EMG electrodes (silver–silver chloride) were used to monitor the muscle activity (EMG). The electrodes were placed bilaterally, in pairs 2 cm apart, and a reference electrode was placed over the acromion process of the scapula. The EMG signals were amplified and then A/D converted with a 12-bit, 8-channel A/D converter at 2048 Hz. The EMG signal was a full wave rectified and low-pass filtered with the second-order Butterworth filter.

The parametric two-way ANOVA test ($p < 0.05$) was employed to compare muscle activity (as independent factors we considered thigh angles (120 and 135 deg) and trunk inclination (–30, –15, 0, 15 and 30 deg)). The Duncan post-hoc test was used to compare the means of the positions. All subjects enjoyed good health and all signed an informed consent form approved by the University of Physical Education. The work has been approved by the ethical committee of the University of Physical Education in Warsaw.

3. Results

Normalized mean values of muscle activity (AEMG) are presented in the table. Each EMG value represents muscle activity during sitting with trunk inclinations at two seatpan angles relatively to their MVC activities.

Seatpan angles did not influence significantly EMG of the trunk extensors (figure 1). The EMG of trapezius was 5% lower in position of 120 deg when the trunk was moved forward and 3.8% higher when trunk was moved backward. EMG of erector spinae did not change myoelectric activity in backward and forward positions of the trunk. 3.5% difference of the EMG was observed in the middle position of the trunk. Additionally, the EMG of TR (18%) and ES (17%) was lower in backward position. However, statistical significance for those differences was confirmed only for ES ($F = 5.13$; $p = 0.001$).

Statistical significance of the seatpan position on EMG of lower extremity muscles was observed. The EMG of rectus femoris (RF) during sitting did not exceed 7% of its MVC activity (figure 2). Although only 4% difference of RF EMG among all trunk angles was observed, the influence of seatpan angle was statistically significant at $p = 0.027$ ($F = 5.20$).

Table. Normalized mean values of muscle activity (AEMG) during sitting in different positions of trunk inclination and seatpan angles relatively to maximal isometric contractions; trapezius p. transversus (TR), erector spinae (ES), rectus femoris (RF), gastrocnemius lat. (GL), tibialis anterior (TA)

Trunk inclination (deg)		Seatpan angle (deg)	Normalized EMG value				
			Muscles				
			TR	ES	RF	GL	TA
Forward	30	120	0.220 ±0.226	0.233 ±0.183	0.045 ±0.037	0.022 ±0.01	0.036 ±0.01
Forward	30	135	0.267 ±0.255	0.238 ±0.159	0.065 ±0.057	0.033 ±0.005	0.061 ±0.01
Forward	15	120	0.195 ±0.167	0.146 ±0.115	0.041 ±0.031	0.018 ±0.007	0.038 ±0.014
Forward	15	135	0.195 ±0.172	0.137 ±0.056	0.077 ±0.091	0.026 ±0.009	0.050 ±0.011
	0	120	0.203± 0.174	0.084 ±0.06	0.033 ±0.024	0.015 ±0.005	0.031 ±0.012
	0	135	0.203 ±0.059	0.049 ±0.034	0.067 ±0.025	0.019 ±0.007	0.069 ±0.037
Backward	–15	120	0.142 ±0.115	0.058 ±0.039	0.046 ±0.035	0.017 ±0.005	0.070 ±0.074
Backward	–15	135	0.127 ±0.024	0.063 ±0.06	0.075 ±0.069	0.020 ±0.008	0.149 ±0.167
Backward	–30	120	0.128 ±0.102	0.063 ±0.039	0.038 ±0.026	0.018 ±0.007	0.093 ±0.077
Backward	–30	135	0.090 ±0.032	0.075 ±0.052	0.051 ±0.032	0.018 ±0.004	0.195 ±0.247

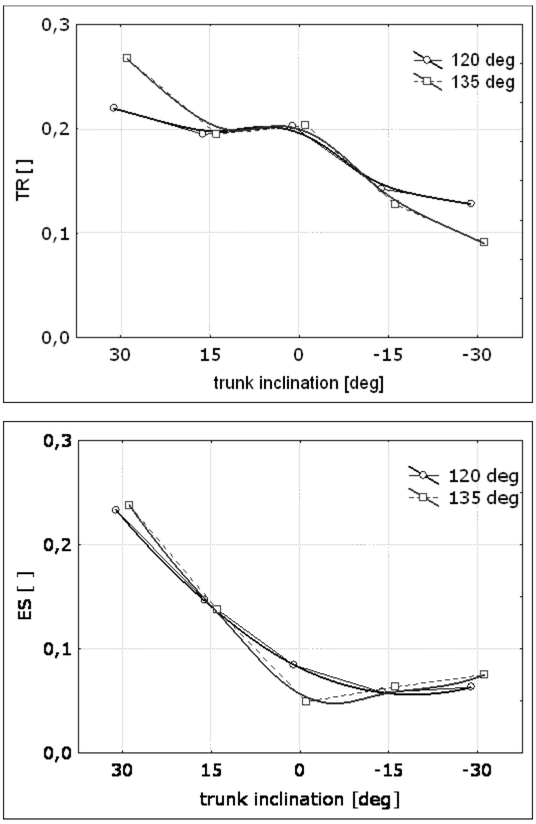

Fig. 1. The influence of seatpan angle (120 and 135 deg – the angle of thigh vs. the perpendicular), trunk inclination ((30 and 15 deg – forward) 0, (–15 and –30 deg – backward)) on the relative AMEG values of back muscles: trapezius p. transversus (TR) and erector spinae (ES)

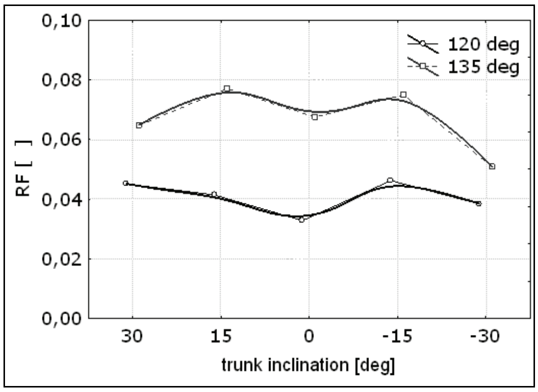

Fig. 2. The influence of seatpan angle (120 and 135 deg – the angle of thigh vs. the perpendicular), trunk inclination ((30 and 15 deg – forward) 0, (–15 and –30 deg – backward)) on the relative AMEG values of rectus femoris (RF)

Normalized activity of gastrocnemius lateralis was twice as low as that of rectus femoris. Both factors: seatpan (F = 6.911, p = 0.011) and trunk (F = 3.61, p = 0.011) angles influenced EMG of this muscle. However, a significant ($p < 0.05$) influence of seatpan adjustment on EMG was confirmed only when trunk was inclined to the position of 30 and 15 degrees. Moreover, significantly lower EMGs were recorded for all trunk inclination of 30 deg but only at seatpan adjusted to 135 deg.

An opposite direction of the activity of tibialis anterior was noticed for other muscles described in this

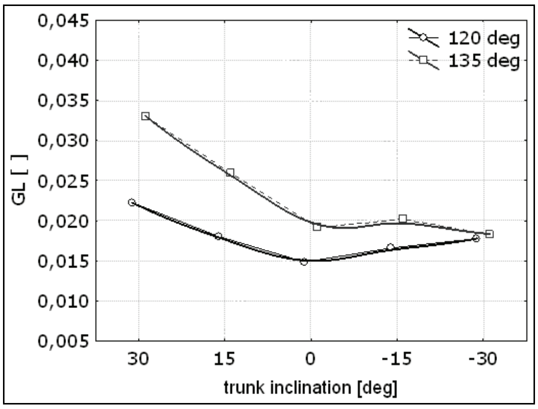

Fig. 3. The influence of seatpan angle (120 and 135 deg – the angle of thigh vs. the perpendicular), trunk inclination ((30 and 15 deg – forward) 0, (–15 and –30 deg – backward)) on the relative AMEG values of gastrocnemius lateralis

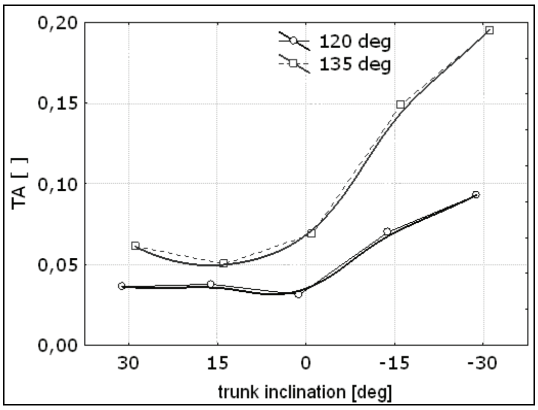

Fig. 4. The influence of seatpan angle (120 and 135 deg – the angle of thigh vs. the perpendicular) and trunk inclination ((30 and 15 deg – forward) 0, (–15 and –30 deg – backward)) on the relative AMEG values of tibialis anterior

paper. That effect was over twice stronger for EMG recorded at seatpan adjusted to 135 deg. EMG was significantly influenced by both factors: seatpan (F = 5.348, p = 0.024) and trunk (F = 3.319, p = 0.017). However, only for the seatpan agle adjusted to 135 deg, EMG recorded at trunk position of –30 deg was significantly higher than EMG recorded at 0, 15 and 30 deg ($p < 0.05$).

4. Discussion

Standing up to sitting down should be treated as a postural transition which is performed many times each day. Rising from a sitting position is considered as one of the most difficult and mechanically demanding functional operations. KERR et al. [34], [35] describe rising from the sitting position as a functional ability that is one of the basic prerequisites for walking. Without this natural ability our independence would be lost. In older people, pregnant woman and people with joint disorders (hip, knee) this ability is limited [36]. Prolonged sitting poses a potential risk in the development of low-back pain [37]. Static loading of the musculoskeletal system is generally more likely to produce discomfort than dynamic loading and fixed sitting postures impose a static load on the musculoskeletal system. It is suggested that prolonged sitting may lead to spinal disorders, but the examination has provide no evidence of this, and the results from this series of studies indicate that although prolonged immobile sitting postures produce feelings of discomfort, they probably do not produce any spinal damage.

The advantages of forward inclined seats are limited, up to this time, only to some professions. First of all, people with considerable mobility should take this type of chair. However, the results of this work show the limitation of the seat inclination. As result of seat adjusting to 135 deg, the EMG of lower extremity muscles was more than twice higher compared to that to 120 deg. Moreover, EMG of trunk muscles did not depend on seat inclination. ANDERSON and HELANDER [38] also investigated the effects of a forward inclined seatpan (0°, 15° and 30°), with and without a backrest, on the pressure in the lumbar spine, using EMGs. Their studies indicate that an increase in forward slope up to an absolute maximum of 15° decreases spinal load, whereas greater seat slopes result in an increased loading, but the results depend on the presence of a backrest. Mid- and upper-back comfort were improved by the forward seat inclination, but leg comfort decreased. Prolonged sitting with the forward leaning posture should affect a leg pain, especially in its external part. We proved that 15-deg trunk deviations did not influence the muscle activity. Some studies showed that if the user reclined as little as 20 degrees, the backrest could carry up to 47% of the upper body weight [39], [40]. Our results indicate that 30 deg of forward bending of the trunk significantly increased EMG (20%) of the trunk extensors and back side of the leg. Reverse inclination was responsible for a higher activity of tibialis anterior only. This effect is more than twice higher for 135 deg of seatpan slope. In our opinion, this position of the trunk influences on the position of the center of gravity and this displacement may result in unsupported foot position. BIDARD et al. [41] also revealed that the stabilization effort was greater for unsupported sitting than for standing because of not optimal alignment of the centers of mass.

5. Conclusions

1. Unsupported sitting position did not influence significantly muscles' activity in the range of ±15-deg trunk inclination. Higher back leaning may result in unsupported foot position and trunk support is required.

2. The slope of seatpan affects only muscle activity of lower extremities.

Acknowledgements

The work supported by the Polish Ministry of Science and Higher Education, grant no N R16 0001 04.

References

[1] HÄGG G.M., *Static workloads and occupational myalgia – a new explanation model*, [in:] P.A. Anderson, D.J. Hobart and J.V. Danoff (eds.), *Electromyographical kinesiology*, Elsevier, Amsterdam, 1991, 141–143.

[2] WESTGAARD R.H., DELUCA C.J., *Motor unit substitution in long-duration contractions of the human trapezius muscle*, Journal of Neurphysiology, 82, 501–504.

[3] EVANS W., JOBE W., SEIBERT C., *A cross-sectional prevalence study of lumbar disc degeneration in a working population*, Spine, 1999, 14, 60–64.

[4] VIDEMAN T., NURMINEN M., TTROUP J.D.G., *Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading*, Spine, 1990, 15, 728–740.

[5] EKLUND J.A.E., CORLETT E.N., *Evaluation of spinal loads and chair design in seated work tasks*, Clinical Biomechanics, 1987, 2, 27–33.

[6] ALTHOFF I., BRINCKMANN P., FROBIN W., SANDOVER J., BURTON K., *An improved method of stature measurement for quantitative determination of spinal loading*, Spine, 1992, 17(6), 682–693.

[7] SALEWYTSCH A.J., CALLAGHAN J.P., *Can quantified lumbar spine postures and trunk muscle activation levels predict discomfort during prolonged sitting?* 31st Annual Conference of ACE, Ergonomics and Safety (Hull: Association of Canadian Ergonomists), 1999.

[8] KROEMER K.H.E., *Sitting (or standing?) at the computer workplace*, [in:] R. Leuder and K. Noro (eds.), *Hard Facts about Soft Machines*, Taylor & Francis, London, 1994, 181–191.

[9] SERBER H., *The study of lumbar motion in seating*, [in:] R. Leuder and K. Noro (eds.), *Hard Facts about Soft Machines*, Taylor & Francis, London, 1994, 423–431.

[10] SUZUKI Y., SUGANO T., KATO T., *An ergonomic study of dynamic sitting*, [in:] R. Lueder and K. Noro (eds.), *Hard Facts about Soft Machines*, Taylor & Francis, London, 347–373.

[11] JENSEN C.V., BENDIX T., *Spontaneous movements with various seated workplace adjustments*, Clinical Biomechanics, 1994, 7, 87–90.

[12] Van DIEEN J.H., de LOOZE M.P., HERMANS V., *Effects of dynamic office chairs on trunk kinematics, trunk extensor EMG and spinal shrinkage*, Ergonomics, 2001, 44(7), 739–50.

[13] KROEMER K.H.E., GRANDJEAN E., *Fitting the task to the human*, Taylor and Francis, London, 1997.

[14] SCHOBERTH H., *Orthopaedie des Sitzens*, Springer Verlag, Berlin, 1989.

[15] ZACHARKOW D., *Posture: Sitting, Standing, Chair Design and Exercise*, Charles Thomas, Springfield, USA, 1988.

[16] PHEASANT S., *Bodyspace: Anthropometry, Ergonomics and Design*, Taylor & Francis, London, 1986.

[17] KIMURA S., STEINBACH G.C, WATENPAUGH D.E., HARGENS A.R., *Lumbar spine disc height and curvature responses to an axial load generated by a compression device compatible with magnetic resonance imaging*, Spine, 2001, 26, 2596–2600.

[18] WILKE H.J., NEEF P., CAIMI M., HOOGLAND T., ALES L.E., *New in vivo measurements of pressures in the intervertebral disc in daily life*, Spine, 1999, 24 (8), 755–762.

[19] ROHLMANNT A., CLAES L.E., BERGMANNT G., GRAICHEN F., NEEF P., WILKE H.J., *Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises*, Ergonomics, 2001, 44(8), 781–94.

[20] PEZOWICZ C., KACZMAREK B., BĘDZIŃSKI R., *Application of miniature pressure transducers to the investigation of intradiscal pressure in the cervical spine*, Acta of Bioengineering and Biomechanics, 2004, 6(2), 23–32.

[21] KEEGAN J.J, *Alterations of the lumbar curve related to posture and seating*, J. Bone and Joint Surg., 1953, 35(3), 589–603.

[22] BRANTON P., *Behaviour body mechanics and discomfort*, Ergonomics, 1969, 12(2), 316–327.

[23] GRANDJEAN E., HÜNTING W., *Ergonomics of posture – Review of various problems of standing and sitting posture*, Applied Ergonomics, 1977, 8(3), 135–140.

[24] BENDIX T., *Sitting postures – a review of biomechanical and ergonomic aspects*, Manual Medicine, 1986, 2, 77–81.

[25] CORLETT E.N., MANANICA I., *The effects and measurement of working postures*, Applied Ergonomics, 1980, 11(1), 7–16.

[26] MANDAL A.C., *The seated man: Homo sedens. The seated work position theory and practice*, Applied Ergonomics, 1981, 12(1), 19–26.

[27] LELONG C., DREVET J.G., CHEVALLIER R., PHELIP X., *Spinal biomechanics and the sitting position*, Rev. Rhum. Mal. Osteoartic., 1988, 55, 375–80.

[28] BENDIX T., *Seated trunk posture at various seat inclinations, seat heights, and table heights*, Human Factors, 1984, 26, 6, 695–703.

[29] BENDIX T., KROHN L., JESSEN F., AARAS A., *Trunk posture and trapezius muscle load while working in standing, supported-standing, and sitting positions*, Spine, 1985, 10, 5, 433–439.

[30] MANDAL A.C., *Work chair with tilting seat*, Ergonomics, 1976, 19(2), 157–164.

[31] MANDAL A.C., *The seated man*, Dafnia Publications, Denmark, 1985.

[32] MANDAL A.C., *Investigation of the lumbar flexion of the seated man*, International Journal of Industrial Ergonomics, 1991, 8, 75–87.

[33] ANDERSON G.B.J., MURPHY R.W., ORTENGREN R., NACHEMSON A.L., *The influence of backrest inclination and lumbar support on lumbar lordosis*, Spine, 1979, 4, 52–58.

[34] KERR K.M., WHITE J.A., BARR D.A., MOLLAN R.A.B., *Standardization and definitions of the sit-to-stand cycle*, Gait and Posture, 1994, 2, 182–190.

[35] KERR K.M., WHITE J.A., BARR D.A., MOLLAN R.A.B., *Analysis of the sit-to-stand movement cycle in normal subjects*, Clinical Biomechanics, 1997, 12, 236–245.

[36] LORD S.R., MURRAY S.M., CHAPMAN K., MUNRO B., TIEDEMANN A., *Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people*, J. Gerontol. A Biol. Sci. Med. Sci., 2002, 57(8), 539–543.

[37] HALES T.R., BERNARD B.P., *Epidemiology of work-related musculoskeletal disorder*, Orthopedic Clinics of North America, 1996, 27, 679–709.

[38] ANDERSON L.M., HELANDER M.G., *The effects of spinal shrinkage and comfort of a forwardly-inclined seat with and without a backrest*, Proceedings of the International Ergonomics Association Conference on Human Factors in Design for Manufacturability and Process Planning, 1990, 1–10.

[39] GRANDJEAN E., HUNTING W., PIDERMANN M., *VDT workstation design: preferred settings and their effects*, Human Factors, 1983, 25, 161–175.

[40] CORLETT E.N., EKLUND J.A.E., *How does a backrest work?* Applied Ergonomics, 1984, 15, 111–114.

[41] BIDARD C., RIENSTRA S., VELTINK P.H., KOOPMAN H.F.J.M., GRADY J., DE VRIES J., HUTTENHUISM L., *Trunk stability while standing or sitting: a static analysis*, IFESS2000 Conference at Aalborg University, Denmark, 2000.