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Effect of seat and table top slope on the biomechanical stress sustained by the musculo-skeletal system

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ABSTRACT

The purpose of this study was to assess the effect of table and seat slope on the biomechanical stress sustained by the musculo-skeletal system. Angular position of the head and trunk, and surface electromyography of eleven postural muscles were recorded while seated under different conditions of seat slope (0°, 15° forward) and table slope (0°, 20° backward). The specific stress sustained by C7-T1 joint was estimated with isometric torque calculation. The results showed that the backward sloping table was associated with a reduction of neck flexion and neck extensors EMG, contrasting with a concurrent overactivity of the deltoideus. The forward sloping chair induced an anterior pelvic tilt, but also a higher activity of the knee (vasti) and ankle (soleus) extensors. It was concluded that sloping chairs and tables favor a more erect posture of the spine, but entails an undesirable overactivity of upper and lower limbs muscles to prevent the body from sliding.

1. Introduction

The most widespread work posture today in industrialized countries is sitting, which induces biomechanical stress on the osteoarticular chain. This stress firstly results from the gravity force that produces a compressive load on the intervertebral discs, as attested by in vivo measurements in the lumbar spine [1–3]. Secondly, the flexion of the thighs and of the spine associated with the seated posture may also increase the load applied on the osteoarticular chain. Indeed, larger hip flexion changes lumbar curvature toward a more flexed position [4–7], which is associated with higher intradiscal pressure [2,3,8].

Referring to some of the studies quoted above, and in an attempt to prevent back pain, many authors have advocated the use of "ergonomic" workstations, whose main principle is to reduce lumbar and neck flexion while seated. Concerning the lumbar spine, they consist of sloping seats from 5° to 25° [9–14], aimed at "re-establishing" the lumbar lordosis in the seated posture. These seats were assumed to limit the backward pelvic tilt and the lumbar flexion occurring with the transition from standing to sitting [11,12,14]. However, this effect may not be systematic because it did not prove to be significant in a study by Bendix [13], and Bridger [14] described a large inter-individual variability in postural adaptation to workspace.

Concerning the cervical spine, most authors focused on the characteristics of the table, promoting the use of a backward sloping table top (from 10° to 45°) to favor a more upright posture of the head and neck [11,14–17]. As for sloping seats, a wide variety of postural adaptations were observed among subjects [17], questioning the real efficiency of such an item of furniture. In addition, no data were provided on the destabilizing torque due to gravity, which is essential to quantify the stress sustained by the cervical joints.

When considering table and chair as two variable parts of a single workstation, the question arises as to whether an interaction exists between the effects of their respective slopes on body posture. In other words, does the use of a sloping table alter the effects of a sloping chair on posture, and vice versa? To date, only the study by Bridger [14] included conditions mixing flat and sloping surfaces (flat table with sloping chair and vice versa), but the sloping chair was equipped with a 45° knee pad that locks the lower limbs into a very specific posture. Hence, this question needs to be explored further, all the more as it might provide relevant information on the optimal combinations between seat and table.

Both "ergonomic" table and chair are based on sloping surfaces, which induce an undesirable sliding-down effect

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related to the additional tangential component of gravity. As a result, the forearms resting on the table top should be driven backward and downward (backward sloping table top) and the pelvis forward and downward (forward sloping seat). In order to keep the body steady, this effect must be countered by additional muscular activity, possibly located in the thighs and shoulders. An in-depth analysis of this mechanism is required to determine to what extent it might be stressful for the musculo-skeletal system.

The objective of this study was to assess the effect of sloping seats and tables on the biomechanical stress sustained by the musculo-skeletal system. To this aim, angular measurements and EMG recordings were taken along the postural chain while seated with different combinations of table and seat slopes.

2. Methods

2.1. Participants

Twelve asymptomatic male participants, who were free from any recent neurological and musculo-skeletal disease, took part in this study. The mean (±SD) age, height, weight and body mass index were 20.4 (±1.5) years, 179(±5) cm, 72.9 (±8.8), 22.8 (±2.5) kg/m^2, respectively. Experiments were approved by the local ethics committee, and complied with the Helsinki declaration. A written informed consent form was returned by all participants.

2.2. Materials

2.2.1. Electromyography

A 16-channel wireless EMG device (Zéro Wire model, Aurion, Milan, Italy) was used to assess the surface electrical activity of the main postural muscles in the seated posture, with different conditions of chair and table slope.

Eleven superficial muscles of the trunk, neck, shoulder and lower limbs were selected after a pre-test series: neck extensors, trapezius pars descendens, deltoideus pars clavicularis, rectus abdominis, erector spinae at T4, T11 and L3 levels, rectus femoris, vastus lateralis, vastus medialis, and soleus.

The subjects' skin was shaved where needed, abraded and cleaned with alcohol to reduce skin impedance to below 5 kΩ. 10-mm diameter (conductive area) Ag/AgCl pre-gelled disposable surface electrodes (PG10S, FIAB, Vicchio, Italy) were applied in a bipolar configuration over the muscle belly and in line with muscle fibers direction, on the dominant side of the body. The inter-electrode distance was 20 mm for all sites. All electrode placements were confirmed using palpation and manual resistance tests.

To allow for normalization of the EMGs signals by their maximum values, two 3-s isometric maximal voluntary contractions (MVC) were first carried out for each muscle. Recordings were subsequently taken during the four experimental conditions.

The individual EMG signals were digitized at 1000 Hz using a CompactDAQ with 9215 modules (National Instrument, Austin, USA), controlled by a custom program designed using Labview software (National Instrument, Austin, USA). For each muscle, average rectified EMGs were calculated from the complete recordings, and the values were expressed as a percentage of the data obtained in MVC (normalized EMG).

2.2.2. Inertial orientation system

The angular positions of the head, spine and pelvis in the sagittal plane were recorded using a three-degree-of-freedom orientation inertial system (Inertia Cube3, Intersense Inc., Billerica, USA). It is composed of four wireless trackers (IC3) transmitting data to a USB receiver connected to a computer. Orientation data were collected and synchronized with EMG signals, using a custom-developed Labview program (National Instrument, Austin, USA).

The first tracker was placed on top of the head, at the junction between the two parietal bones, using a system of Velcro bands. The second and the third trackers were adhered to the skin with double sided tape, at the levels of T1 and S1 spinous processes.

2.2.3. Chairs and table

Two types of chairs and one table (Héphaïstos, Rivière sur Tarn, France), which were all height-adjustable were used for the experiment (Fig. 1). One chair had a flat seat (S0 condition), and the other, which was specifically designed for the purpose of the experiment, had a 15° forward sloping seat (S15 condition), as recommended by Mandal [9]. The table top was set in a flat position (T0 condition) or with a backward slope of 20° (T20 condition). This slope value was considered as average relative to the angles described in previous studies, which range from 10° to 45° [11,15,16]. A special steel ruler with a raised edge was mounted on the table top to prevent the book from sliding.

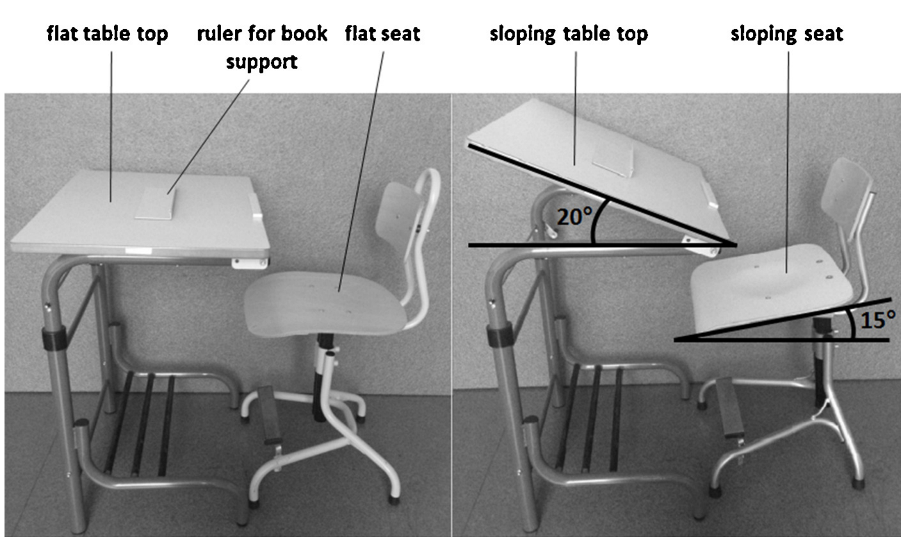

Fig. 1. Adjustable table and chair used for the experiment.