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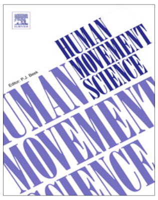

# The effect of force-controlled biting on human posture control

D. Hellmann[a,*], T. Stein[b,f], W. Potthast[c,d], P. Rammelsberg[a], H.J. Schindler[a,e], S. Ringhof[b]

[a] *Department of Prosthodontics, University of Heidelberg, Heidelberg, Germany*
[b] *Institute of Sports and Sports Science, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany*
[c] *Institute of Biomechanics and Orthopaedics, German Sport University Cologne, Cologne, Germany*
[d] *ARCUS Clinic Pforzheim, Pforzheim, Germany*
[e] *Research Group Biomechanics, Institute for Mechanics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany*
[f] *BioMotion Center, Institute of Sports and Sports Science, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany*

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## ABSTRACT

Several studies have confirmed the neuromuscular effects of jaw motor activity on the postural stability of humans, but the mechanisms of functional coupling of the craniomandibular system (CMS) with human posture are not yet fully understood. The purpose of our study was, therefore, to investigate whether submaximum biting affects the kinematics of the ankle, knee, and hip joints and the electromyographic (EMG) activity of the leg muscles during bipedal narrow stance and single-leg stance. Twelve healthy young subjects performed force-controlled biting (FB) and non-biting (NB) during bipedal narrow stance and single-leg stance. To investigate the effects of FB on the angles of the hip, knee, and ankle joints, a 3D motion-capture system (Vicon MX) was used. EMG activity was recorded to enable analysis of the coefficient of variation of the muscle co-contraction ratios (CVR) of six pairs of postural muscles. Between FB and NB, no significant differences were found for the mean values of the angles of the ankle, knee, and hip joints, but the standard deviations were significantly reduced during FB. The values of the ranges of motion and the mean angular velocities for the three joints studied revealed significant reduction during FB also. CVR was also significantly reduced during FB for five of the six muscle pairs studied. Although submaximum biting does not change the basic strategy of posture control, it affects neuromuscular co-contraction patterns, resulting in increased kinematic precision.

## 1. Introduction

Human posture control delineates the ability to control balance and orientation of the body (Loram & Lakie, 2002). The biological static equilibrium during upright stance is characterized by inherent instability. Corrective intermuscular and intramuscular muscle synergy and changes in the coordination of the different body segments are needed to counteract these periodic destabilizing oscillations (Peterka & Loughlin, 2004). The primary inputs utilized to adapt posture are sensory information from the visual, vestibular, and somatosensory systems, which are transmitted to the central nervous system (CNS), where the input is weighted in accordance with actual static requirements (Loram & Lakie, 2002; Peterka & Loughlin, 2004). In recent years, the effect of the craniomandibular system (CMS) on the control of human posture has

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* Corresponding author at: Im Neuenheimer Feld 400, 69120 Heidelberg, Germany.
*E-mail address:* daniel.hellmann@med.uni-heidelberg.de (D. Hellmann).

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attracted increasing interest. Neuroanatomical animal studies have revealed trigeminal projections to all levels of the spinal cord (Devoize et al., 2010; Ruggiero, Ross, & Reis, 1981), and numerous nerve connections of the N. trigeminus to neural structures involved in posture control have been found, e.g. reciprocal projections between the trigeminal sensory nucleus and vestibular nuclei in rats (Buisseret-Delmas, Compoint, Delfini, & Buisseret, 1999; Giaconi et al., 2006; Marfurt & Rajchert, 1991), and direct trigeminal projections to areas of the cerebellum, which are involved in the control and coordination of eye–head movements (Billig, Yatim, Compoint, Buisseret-Delmas, & Buisseret, 1995). In humans, few studies have documented trigeminovestibular modulation (Deriu et al., 2000, 2007), but it has been suggested that trigeminal modulation of vestibular activity affects the control of posture (Troiani & Petrosini, 1981). A further, but so far unproved, concept in this context is the assumption of biomechanical coupling of the CMS and other body-segments via fascial-muscle chains (FMC) (Chaudhry, Bukiet, Ji, & Findley, 2011; Richardson, Hides, Wilson, Stanton, & Snijders, 2004). It has been speculated that muscular activity of the craniomandibular system might be transmitted along these FMCs to the distal musculature, altering human posture (Cuccia & Caradonna, 2009; Munhoz & Marques, 2009; Tecco, Salini, Tete, & Festa, 2007; Valentino, Fabozzo, & Melito, 1991; Valentino & Melito, 1991).

To clarify the physiological significance of these neuromuscular and biomechanical connections of the CMS, research in recent decades has studied the effect of biting on natural dentition or occlusal devices by means of electromyography or posturographic measurements. EMG studies focusing on modulation of neuromuscular effects at the lower extremities in response to oral clenching revealed significant nonreciprocal facilitation of ankle extensor and flexor muscles, and attenuated reciprocal Ia inhibition of the pretibial muscles and the soleus muscle. On the basis of these results, the authors concluded that voluntary teeth clenching contributes to improvement of the stability of stance (Boroojerdi, Battaglia, Muellbacher, & Cohen, 2000; Miyahara, Hagiya, Ohyama, & Nakamura, 1996).

Other studies, in which posturographic analysis was conducted on healthy subjects, also confirmed neuromuscular effects of jaw motor activity on human posture control, in the form of stabilization of upright posture during bipedal stance (Bracco, Deregibus, & Piscetta, 2004; Gangloff, Louis, & Perrin, 2000; Hellmann, Giannakopoulos, Blaser, Eberhard, & Schindler, 2011; Kushiro & Goto, 2011; Sakaguchi et al., 2007; Sforza et al., 2006; Tardieu et al., 2009). Recent results have, furthermore, shown that oral motor activity enhances posture stability in bipedal stance for patients with peripheral or central vestibulopathies (Goto, Kushiro, & Tsutsumi, 2011). In most of the publications, unfortunately, descriptions of the experimental jaw positions and bite-forces are inadequate.

There is, however, evidence of a significant and reproducible stabilizing effect of controlled submaximum biting tasks on human body-sway during hip-width stance among healthy subjects, apparent as a reduced area of the center of pressure (COP). Reduction of the COP area was, moreover, greatest during biting on a hydrostatic system at submaximum force levels of 100–200 N (Hellmann, Giannakopoulos, Blaser, Eberhard, Rammelsberg, et al., 2011; Hellmann, Giannakopoulos, Blaser, Eberhard, & Schindler, 2011). In a recently published study we showed that submaximum biting significantly improved posture control, in particular, under more challenging conditions in terms of bipedal narrow stance and unipedal stance. The measured reductions in the sway of the COP were accompanied by reduced trunk and head oscillations (Ringhof, Stein, Potthast, Schindler, & Hellmann, 2015). However, none of the mentioned posturographic studies investigated the underlying neuromuscular mechanism of the measured phenomena.

The purpose of this study was, therefore, to investigate, concurrently, the neuromuscular responses to, and kinematic effects of, submaximum biting on human posture control for healthy young adults, by means of a combination of kinematic and EMG analysis of the lower extremities. It was hypothesized that controlled submaximum biting tasks would provoke changes in joint kinematics and in the patterns of muscle co-contraction in bipedal narrow and unipedal stance.

## 2. Materials and methods

### 2.1. Subjects

Twelve healthy subjects, ten males and two females (age 21.8 ± 1.8 years) with a body-mass index of 22.9 ± 3.7 kg/m$^2$ participated in our study. Their reported weekly physical activity was 2.3 ± 1.2 h. The participants had normal vision, and no muscular or neurological diseases in their medical history. They also had no temporomandibular disorders (assessed by means of the RDC/TMD criteria (Dworkin & LeResche, 1992)), and presented with full dentition (except for 3rd molars) in neutral occlusion. All subjects were naïve to the experiments. The study was approved by the Ethics Committee of the German Sport University Cologne (No. 38/12). All participants gave their written informed consent to the experiments, which were conducted in accordance with the Declaration of Helsinki.

### 2.2. Instrumentation

To investigate the effect of submaximum biting on joint kinematics a 3D motion-capture system (Vicon Motion Systems, Oxford, UK) was used. Coordinates of reflective markers in three dimensions were collected by means of thirteen infrared cameras (Vicon MX camera system) sampling at 200 Hz. The markers were placed on the skin of the participants in accordance with the Vicon Plug-In Gait full-body marker set (Vicon-Motion-Systems, 2010), and anthropometric measurements were obtained (Table 1, Fig. 1).