Original article

The acute effect of the tongue position in the mouth on knee isokinetic test performance: a highly surprising pilot study

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Summary

The tongue involvement within the isokinetic knee extension/flexion exercises has been investigated. Eighteen participants randomly underwent isokinetic testing at 90 and 180°/s with three different tongue positions: middle position (MID, thrusting on the lingual surface of incisive teeth), lying on the lower arch of the mouth (LOW) and extended up to the palatine spot (UP). Statistical analysis of the data revealed an about 30% significant increase of knee flexion peak torque in UP with respect to MID at both angular speeds. Such a difference could have had a confounding effect on results from numerous past studies using isokinetic knee flexion testing. This study alerts future researchers about standardization of tongue position and warrants further investigations on the explicative processes of this phenomenon.

KEY WORDS: isokinetic test; knee flexion; maximum peak torque; tongue position; CNS path.

Introduction

The tongue is a bodily organ assigned mainly to swallowing. It is also involved in chewing, speech and respiration[1]. The palatine spot is a place in the mouth ceiling in correspondence of the palatine bone between the inter-dental papilla of the upper front teeth and the first fold of the palate. There are at this site trigeminal nerve endings and most of all lots of exteroceptors either in rhesus monkeys, a species phylogenetically linked to humans[2]. Literature provides indications also at central level about the involvement of the tongue in several complex movements globally ruled by the central nervous system (CNS), particularly about swallowing and mastication[3,5].
During exercise, the CNS manages the torque development within a specific joint by means of two specific adjustments: (i) by prolonging the agonist muscle activity, and (ii) by phase shifting the activation peak of antagonist muscles[4]. In this context, it has recently been shown that different tongue-training types induced different cortical plasticity[5]. A further step could be to investigate some tongue involvement within some joint movements[6].
From practical field experience with some athletes describing their own way to manage powerful exercise output, it results that the power output of a joint movement could be influenced by the tongue position in the mouth while performing such strong tasks. The usual position of the tongue is described as lying on the lower arch of the mouth or extended up to the palatine spot depending on authors[7-11].
To test this hypothesis, isokinetic testing, a simple methodology commonly used in laboratory, could help investigating the influence on strength development according to the tongue position. In this context, isokinetic testing is an effective and established measurement technique to assess torque developed by specific muscular groups[12]. Isokinetic testing is the gold standard to study the knee extension/flexion torque/joint angle at the intermediate velocities of 90 and 180°/s[13,14]. From the perspective of an average researcher aiming to perform a standard or specific isokinetic test, most of his or her attention would obviously be focused on each single joint object of investigation rather than on the position of the tongue. The position of the tongue of the exercising subject is hardly visible by the researcher. He would not care about that unless a reasonable doubt could be raised about its' effect on the test results. Together with circadian rhythms, testing time, environment conditions, and subject position, we hypothesize that the position of the tongue could also fall within gen-

eral guidelines for some isokinetic test[15,16]. Therefore, the aim of the present pilot study was to investigate eventual effects due to different tongue's postures in the mouth on knee isokinetic testing outcomes.

Materials and Methods

Subjects

After local University ethical approval for a protocol in line with the guidelines of the Declaration of Helsinki, and written informed consent of the subjects, eighteen healthy male subjects (age 26.6±4.5 yrs; body mass 74.4±7.9 kg, height 175.0±7.7 cm) volunteered to participate in the study. All were recreational athletes without known cardiovascular, neurological or orthopaedic problems. Subjects refrained from drinking alcohol or caffeine-containing beverages for 24 hours before testing, and fasted for at least 4 hours prior to visiting the laboratory so as to reduce any interference from nutrition on the experiment. Subjects underwent a screening to assess their usual position of tongue by an orthodontist. Each subject completed all trials in the same time of the day to eliminate any influence of circadian variation[15]. After being informed of the procedures, methods, benefits and possible risks involved in the study, each subject reviewed and signed an informed consent to participate in the study.

Experimental procedure

As to medical check, all the participants were in good general health conditions at the time of the study and they carried out the test during the same period (middle of September, start of the sport season). Each subject already had at least three weeks of training before the first test. Subjects practiced running (*n* = 6), basketball (*n* = 6) and soccer (*n* = 6). The relevant data were acquired from 9:00 a.m. until 12:00 a.m. with an average temperature of 23°C (min 22, max 24°C). In all experiment, for each participant, it was firstly defined the dominant lower limb (the limb that they use for shooting a soccer ball). For all the subjects, only the dominant lower limb (the right leg for all) was assessed. Each subject wore sportswear and the experiment was conducted in the nursing home 'San Michele' (Maddaloni, Caserta, Italy). Before the test, each participant performed a standardized 10' warm-up[17] on a bike ergometer (Schwinn, Johnny G Pro Spin Bike; crank length: 17 cm) and a 5' standardized active muscular dynamic stretching. Before experimenting, all subjects underwent a test habituation session. The isokinetic testing was conducted in three separate days (in a two weeks duration span, for reliability of measures) with 2 days in-between tests (randomized order) with the tongue in three positions (Fig. 1): (A) middle position, i.e., thrusting on the lingual surface of incisive teeth (MID), (B) lying on the lower arch (LOW); (C) extended up to the palatine spot (UP). The subjects were explicitly asked to maintain the tongue in the prescribed position during the execution of the exercise. The subjects were explicitly advised not to swallow during exercise execution, due that swallowing change tongue position (normally it reaches the UP position). The operators continuously reminded verbally subjects the instructions regarding the positioning of the tongue and monitored it themselves as much as possible. Each condition of tongue position was tested twice for repeatability purposes. The main studied variables were: maximum peak torque (Nm), peak torque/Bw (%), maximum work (J), average peak torque (Nm) and average power (W).

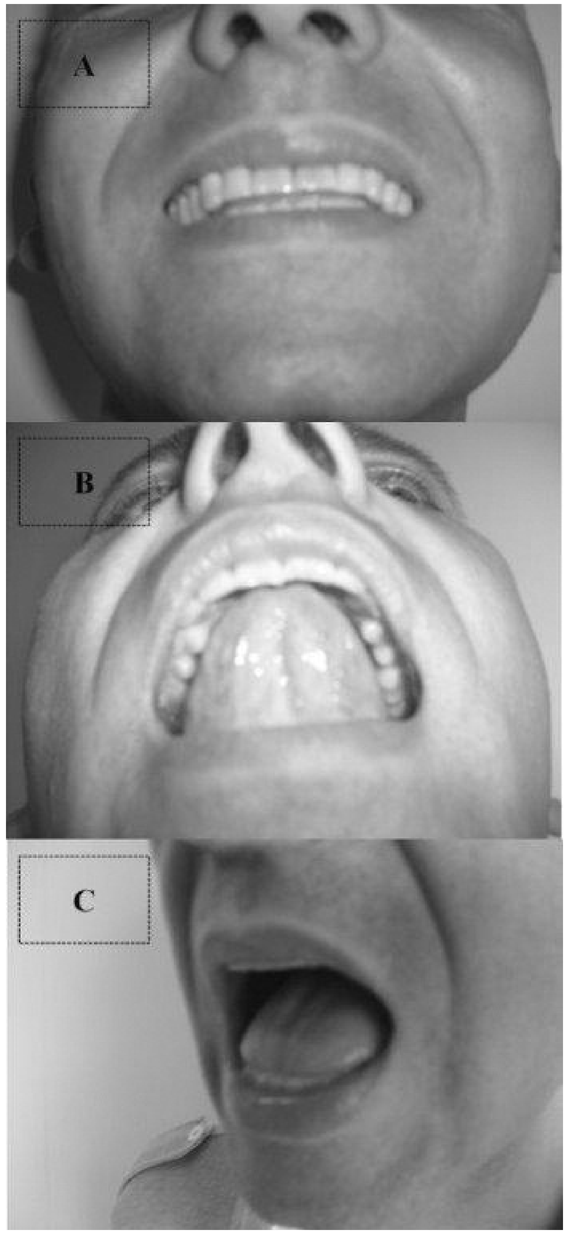

Figure 1. Photographs of the three investigated tongue positions. From top to bottom: (A) middle position, i.e., just behind the front teeth (MID); (B) extended up to the palatine spot (UP); (C) lying on the lower arch (LOW). On the figure, the mouth is open, just to show the tongue's position. During experiments, the mouth was closed.

Isokinetic testing

For the assessment of the knee extensor/flexor torque[14], the participants were positioned on the chair of an isokinetic device (Biodex System 3 pro, Shirley, NY) and exercised with the knee at two slow and fast angular velocities: 90°/s (5 reps) and 180°/s (20 reps) of flexion/extension with 60 s of passive recovery in-between. This same procedure was applied with the different positions of the tongue described above (MID, LOW, UP). Moreover, during this procedure each participant was encouraged by the technical staff to exercise maximally. The isometric torque was recorded by means of the isokinetic dynamometer, whose lever arm was attached 2-3 cm[12] above the lateral malleolus using a non-elastic strap. A harness crossing twice the shoulders and a belt around the abdomen limited the trunk movements. For the assessment of the knee flexion/extension torque, the participants were seated on the isokinetic device, with the hip, knee and ankle joints at ~90°, and the tested lower limb securely fixed to the lever of the device. The other lower limb was fixed to the device at the level of the ankle. Knee torque signal was fed directly from the dynamometer into a 16-bit A/D converter (MP150, Biopac Systems, Goleta, CA), then into a computer sampling at 2 kHz by using the AcqKnowledge software (Biopac Systems, Goleta, CA, USA).

Statistical Analysis

The results are expressed as mean ± standard deviation (SD). The isokinetic variables (i) maximum peak torque (MPT), (ii) maximum peak torque/Body weight unit (MPTB), (iii) maximum work (MW), (iv) average peak torque (APT), (v) average power (AP), (vi) time of acceleration (AC), time of deceleration (DE) were analysed by using a one-way analysis of variance (ANOVA) with repeated measures (MID – LOW – UP tongue position' factor) and Bonferroni *post hoc* test. The sample size has been previously determined with a *post-hoc* statistical power analysis with G-Power 3.1.3 (Heinrich-Heine-University, Düsseldorf, Germany). The assumption of normality was verified by using the Shapiro-Wilk W test. By using the statistical power tool of ANOVA we calculated the total sample size with G-Power 3.1.3. For testing the repeatability of the measure, we performed an Intra-Class Correlation Coefficient (ICC)[19]. The statistical analyses were performed by using the software IBM® SPSS® Statistic version 15.0, (IBM Corporation, Somers, NY, USA). The level set for significance was $p < 0.05$.

Results

All data are presented in Table 1. Comparison of MID - LOW - UP at 90 and 180°/s has shown highly reliable data, with ICC ranging from 0.952 to 0.987. When comparing MPT (90 and 180°/s - flexion/extension) in three conditions (MID – LOW – UP) no significant differences were found ($F_{(1,16)}$= 2.705 with p = 0.070), while ANOVA revealed small differences in AP ($F_{(1,16)}$= 4.101 with p = 0.018), AC ($F_{(1,16)}$= 6.791 with $p < 0.001$), DE ($F_{(1,16)}$= 2.705 with p = 0.002). Moreover, when analyzing angular velocities separately (90 and 180°/s), the data showed that at 90°/s the AP was not different ($F_{(1,16)}$= 2.778 with p = 0.068) while the AC ($F_{(1,16)}$= 4.192 with p = 0.019) was significantly different. While at 180°/s, AP ($F_{(1,16)}$= 1.704 with p = 0.189) and AC ($F_{(1,16)}$= 3.064 with p = 0.052) were not significantly different.

From the analysis after splitting flexion (FX) and extension (EX) phases in 90 and 180°/s (Tab. 1) into three conditions (MID – LOW – UP), the MPT (180°/s EX) was 14% increased (non-significant for MID/UP comparison), while AC was 21% faster ($p < 0.05$ for MID/UP) showing the UP position effect on the isokinetic test results. There was as well an effect as at 90°/s where DE was 50% faster ($p < 0.01$ for UP/MID). Moreover, during FX in both 90 and 180°/s, the effect of the UP position was found significant with respect to the MID position. At 180°/s FX, both MPT and MPTB were 34% higher ($p < 0.05$) for UP/MID (Fig. 2), while at 90°/s the differences for MPT and MPTB was ~+28.5% ($p < 0.05$; UP/MID).

Discussion

The present study showed a significant improvement in the isokinetic knee performance with the tongue in the UP position compared to the tests with the MID and LOW positions (Tab. 1). The improvement occurred at both low (90°/s) and high speeds (180°/s), i.e., during both endurance and high-force muscular exercise, respectively.

What appears clearly striking is the percent difference amount between the flexion MPT values with the different tongue postures, i.e., about +30% with the UP position with respect to the MID one (Tab. 1). Although the results from the present pilot study should considered preliminary, such a difference could have biased, i.e., had a confounding effect, results of lots of past studies about isokinetic testing in healthy subjects, athletes, and acutely and chronically pathological subjects[20-24]. Of interest is to note that not only power variables increased when the tongue was set in a high/palatine position, but also acceleration. This has to be taken into account in future studies in order to investigate, not only force variables, but also kinetics, as contraction speed impacts with power assessments.

The interpretation of the results is quite difficult at present due to the paucity of data in the literature about any relationship between tongue and distal body segments. Indeed, the involvement of the tongue within, e.g., some joints movements is still little known in the scientific community. In this context, we speculate that the upper position of the tongue has relationships with some CNS paths, and therefore induces an appropriate position/status for performing stronger movements

Table 1. Isokinetic data at 90 and 180°/s in flexion and extension phases.

180°/s Extension	MID	LOW	UP	Δ (MID/LOW)	Δ (MID/UP)	Δ (LOW/UP)
max peak torque (Nm)	130±31.66	136±30.63	148±36.59	4.06%	13.56%	9.13%
max peak torque/Bw (%)	176±38.28	184±40.12	199±43.73	4.50%	13.43%	8.55%
maximum work (J)	153±46.58	162±47.65	175±53.04	5.82%	14.66%	8.36%
average peak torque (Nm)	109±27.09	115±24.71	122±30.26	5.51%	12.54%	6.66%
average power (W)	191±54.88	203±53.31	223±62.95	6.11%	16.80%	10.08%
acceleration time (ms)	58±15.78	56±17.42	46±10.16	-3.70%	**-20.99%***	-17.95%
deceleration time (ms)	122±33.78	115±34.59	103±31.48	-5.85%	-15.79%	-10.56%
180°/s Flexion						
max peak torque (Nm)	71±18.57	73±26.85	95±26.23	2.96%	**33.84%***	**29.98%***
max peak torque /Bw (%)	95±23.85	99±38.17	128±33.69	3.52%	**33.73%***	**29.19%***
maximum work (J)	85±31.64	89±43.16	113±38.26	4.55%	32.41%	26.64%
average peak torque (Nm)	58±14.72	60±22.16	74±20.63	3.01%	27.16%	23.44%
average power (W)	96±30.48	102±46.59	129±43.69	6.22%	33.85%	26.01%
acceleration time (ms)	85±32.99	89±32.07	66±26.53	4.20%	-22.69%	-25.81%
deceleration time (ms)	114±26.49	111±20.56	101±24.95	-2.52%	-11.32%	-9.03%
90°/s Extension						
max peak torque (Nm)	180±32.25	174±42.36	192±45.23	-3.19%	6.89%	10.42%
max peak torque /Bw (%)	243±38.35	236±57.04	260±57.42	-2.91%	6.94%	10.14%
max work (J)	210±49.16	205±60.71	221±58.75	-2.30%	5.19%	7.66%
average peak torque (Nm)	165±31.34	162±40.29	181±41.95	-1.72%	9.74%	11.67%
average power (W)	158±36.67	162±44.68	185±49.99	2.36%	16.89%	14.20%
acceleration time (ms)	46±14.47	43±20.16	34±14.99	-7.69%	-27.69%	-21.67%
deceleration time (ms)	156±28.54	104±42.54	78±42.64	-33.49%	**-50.00%†**	-24.83%
90°/s Flexion						
max peak torque (Nm)	87±17.11	90±32.05	112±28.31	3.78%	**28.67%***	23.99%
max peak torque /Bw (%)	119±24.79	124±46.65	152±38.29	4.17%	**28.13%***	23.00%
max work (J)	112±30.72	118±50.05	141±43.05	5.15%	**25.91%†**	19.74%
average peak torque (Nm)	79±16.48	84±31.56	105±26.21	6.53%	33.27%	25.09%
average power (W)	79±22.37	89±37.53	115±32.66	11.76%	**45.68%†**	**30.35%***
acceleration time (ms)	70±35.95	72±32.62	46±18.28	3.06%	-34.69%	**-36.63%***
deceleration time (ms)	113±76.10	91±39.70	77±25.25	-19.62%	-31.65%	-14.96%

Note, the three positions of the tongue: thrusting on the lingual surface of incisive teeth (MID), lying on the lower arch (LOW) and extended up to the palatine spot (UP) during the isokinetic test. Mean data ± SD. (*) p < 0.05 – (†) p < 0.01 in bold type.

with other parts of the body, more precisely, lower limbs as far as this pilot study is concerned. The specificity of the effect, i.e., only on flexion movements, suggests that the tongue might be linked to a CNS path referable to phasic activity (e.g., foot withdrawal) and not to tonic activity (e.g., antigravity pos-

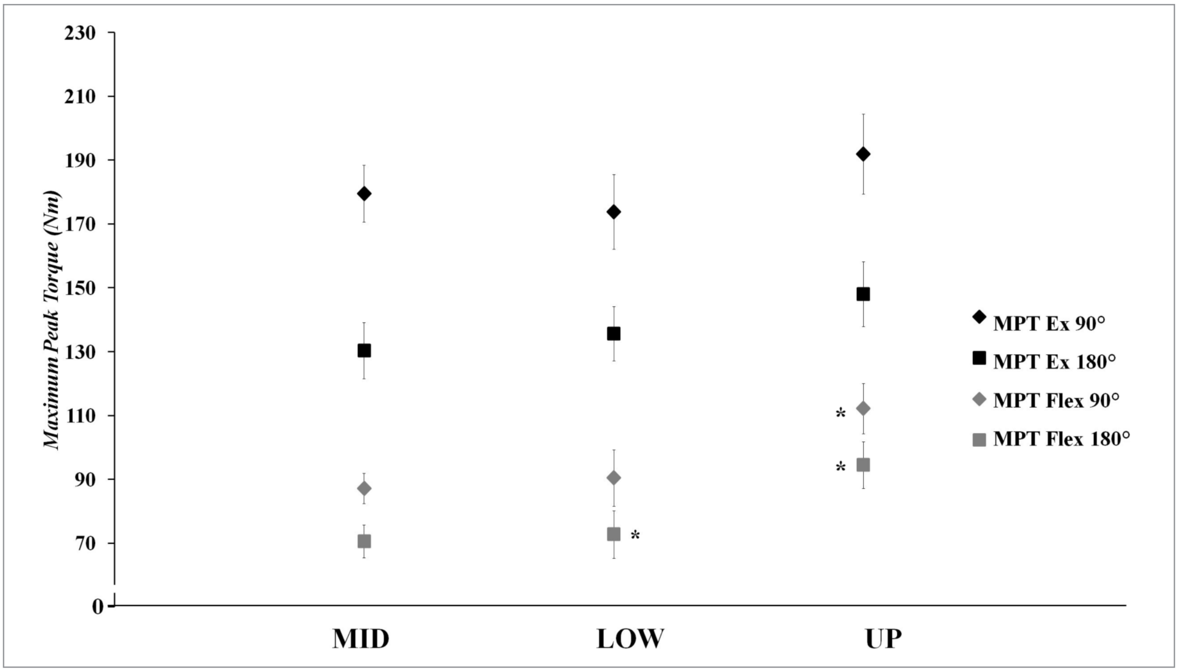

Figure 2. Maximum peak torque (MPT) values over different tongue's postures. Ex, Flex, MID, LOW and UP for extension, flexion, (tongue) thrusting on the lingual surface of incisive teeth, lying on the lower arch and extended up to the palatine spot, respectively. * $p < 0.05$ significant difference of MID and/or LOW compared to UP position.

tural control). Yet, such a topic goes beyond the purpose of this study and should be investigated by using a proper neurophysiological approach/devices.

In conclusion, this study provides relevant indications to prompt researchers aiming to perform some isokinetic testing of knee flexion to control subjects tongue positions, but also provides guidance to assessors to the way they advise assessed subjects on the way they position their tongue inside their mouths. The position of the tongue could therefore fall within the posture variables to check/control in isokinetic testing. Further studies are warranted in order to understand this quite surprising relationship between tongue position and lower limb performance.

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