

STRENGTH AND BITE, PART II: TESTING ISOMETRIC STRENGTH USING A MORA SET TO A FUNCTIONAL CRITERION

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ABSTRACT: The effect on isometric strength of biting on three intraoral devices and habitual occlusion was analyzed. Only subjects who showed a relative weakness to the Isometric Deltoid Press (IDP) when biting as opposed to maintaining the mandible in an unsupported rest position were included in the study. Both in the original 35 subjects and the 23 subjects returning on the second day, performance wearing the appliance set by a functional criterion of peak strength (locking) to the IDP was significantly greater than wearing a placebo appliance and a bite raising appliance that deflected the mandible 1 mm to the left. Strength biting on the appliance set by a functional criterion was significantly greater than all these conditions. Strength biting in habitual trials that were matched with the deflection condition was found to be significantly greater than that biting in the placebo condition. It was concluded that a relationship does exist between bite and isometric strength. Previous speculation about the role of placebo effect was not substantiated by the data gathered in this experiment.

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The research stimulated by Stenger's proposal,¹ that strength of muscles quite removed from the stomatognathic system is affected by mandibular position, is reviewed earlier by Forgione et al.² In this review it was concluded that the original attempts by Smith^{3,4} that supported Stenger's proposed relationship were criticized in a manner that implied that the findings did not merit serious attention.

It was argued by Forgione et al.: (1) The fact that Smith did not perform statistics is no reason to disregard his data because the data were presented so as to permit analysis readily. An analysis of the data did show that a mandibular orthopedic repositioning appliance (MORA) set to a functional criterion did result in significantly greater isometric strength than habitual bite and an unadjusted mouth guard. The functional criterion was a "locking" response to the Isometric Deltoid Press (IDP), a muscle challenge commonly used by chiropractors. (2) Disregarding findings because no placebo control condition was included is a facile criticism. It is incumbent on those who are astute enough to detect an insufficiency in experimental design to replicate the experiment with deficiencies corrected. However, another course was followed by critics. Rather than replications, research was conducted using MORAs of different design (a different independent variable) and testing of isokinetic strength (a different dependent variable). More-

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over, despite the inclusion of a placebo control condition in their experiments, no placebo effect could be demonstrated, i.e., response in the placebo condition was significantly greater than control. Some critical studies even employed a double-blind experiment in order to exclude the influence of placebo using different independent and dependent variables to argue against a relationship between bite and strength. In their concern about placebo effects, these researchers performed multiple independent tests on the same subjects and did not match small samples on baseline performance before assigning to independent groups.⁵⁻⁸ (3) A relationship between isometric and isokinetic strength has not been demonstrated in this field of study. Therefore findings of no difference in isokinetic strength may have no relevance to isometric data. Parker et al.⁹ attempted to set the mandible according to a criterion of maximal isokinetic strength, a functional criterion. Results indicated that performance in the experiment was no different from placebo and control. However, only normals were studied in this experiment. (4) A replication of Smith's findings with improved design was performed in this laboratory by Fuchs¹⁰ but failed to be cited by any researcher in the field. Subjects biting on wax bite positioner fixed according to the IDP criterion (hereafter referred to as a K-MORA) emitted greater isometric strength than acquired centric, placebo, and bite resting open approximately 3 mm.

Because the implications of Stenger's proposal are so far-reaching and since previous findings indicate strongly that mandibular position may affect muscle strength, an experiment was designed that would test isometric strength repeatedly in the same condition. Using subjects as their own control in a two-sequence reversal experiment, the experiment was designed to answer whether bite positioners fixed by a subjective application of the IDP would be associated with higher strength levels when tested objectively.

The purpose of the following experiment was to determine whether there was an objective relationship between mandibular position and isometric strength of the deltoid muscle in subjects selected by the IDP. A demonstration of such a relationship would substantiate earlier clinical indications that in some individuals, a repositioned bite can affect muscles quite removed from the stomatognathic musculature. In addition, since the IDP will be used to position the mandible, results would provide an objective test of the reliability of the kinesiologic technique. Until the phenomenon of apparent increased strength with the IDP can be demonstrated objectively in a controlled ex-

periment, the use of kinesiological testing in dental applications will continue to be regarded as highly questionable.

Subjects were used as their own control to enable statements to be made concerning increase and decrease in strength. To minimize possible fatigue or first trial motivational effects, the first two trials of the experiment were separated arbitrarily from the main experiment to objectively compare strength while biting on the K-MORA and biting habitually. The main experiment was designed to compare strength in three mandibular positions. Aside from the K-MORA, a deflection appliance was included to assess the effect of a lateralizing malocclusion at the vertical dimension established by the IDP. A placebo condition was included using an appliance that did not modify the subject's habitual occlusion. Two measurements were obtained in each of the three experimental biting conditions to evaluate reproducibility of the observations.

Materials and Methods

Only subjects who showed a weaker response to the IDP while biting than to the IDP with the mandible in the unsupported rest position were included in the study.* Thirty-five of 42 male and female volunteers were included in the study. The ages of subjects ranged from 18 to 59 years. They were all lifters of free-weights or Nautilus trainees at a YMCA. Five volunteers were rejected because they did not meet the criterion. Two were rejected because they were able to sustain the weight repeatedly in excess of one minute once the experiment began.

I. Establishing Maximum Sustainable Weight

After mandibular impressions were obtained, each subject was seated and strapped in a Nautilus Lateral Raise exercising device.[†] The device is constructed to isolate action of the anterior, middle, and posterior deltoids in shoulder abduction. The right arm of the device was fitted with a mercury switch that was fixed to show a small green light when the arc of the arm moved from vertical to 100 degrees and a red light at greater than 100 degrees (10 degrees below horizontal). The light was not visible to the subject.

*The reason for this is that if both mandibular positions produced weakness to the IDP, no variation of strength could be detected. If the response to biting were equal to that with the mandible in a relaxed open position, as is frequently found with apparently normal bites, no variation would be expected. These "nonresponders" can confound results because the experimental population would not be homogeneous if they were included.

[†]Exercising device—Nautilus, Inc, Independence, Virginia.

With arms extended horizontally, each subject was instructed to maintain that position to the best of his ability for as long as possible. The arms of the Nautilus device were then lowered onto the extended forearms simultaneously and the timing of a trial began. A trial was terminated when the light changed from green to red.

Subjects were told that the initial phase of the experiment was to determine how strong they were. Each subject was instructed to keep his teeth apart during the trial. Then in a series of trials spaced by five-minute rests, weights were increased until the weight could be sustained at least five but no more than 10 seconds. This weight was reduced by 20 pounds and the diminished weight was used throughout the experiment. Experimental weights ranged from 40 to 235 pounds with a mean of 161.8 pounds.

II. Mandibular Repositioning Devices

During the week that followed, heated Dentsply acrylic[†] was pressed over plaster model of mandibular impressions in a Dentsply Vacupress. Three devices were fashioned for each subject.

A. K-MORA. The contact and labial surface of the incisors and canines were cut away so as to form a lingual bar. The device extended from 1 cm below the gingival margin lingually, over the occlusal surface to the gingival margin on the labial surface of the teeth. When missing teeth were encountered, the spaces were filled with fast-set acrylic monomer. Each device was then equilibrated intraorally so that occlusal contact was distributed evenly on the bicuspids, premolars, and molars. The device was then equilibrated to a vertical dimension determined by maximal resistance to the IDP. This test was performed on both arms. Where needed, the vertical dimension was increased by having the subject bite slowly into partially set, acrylic monomer. Equilibration of the device continued until maximum resistance of "locking" was obtained from each arm. In no case was the vertical dimension increased more than 3 mm.

B. Mandibular Deflection Device. Acrylic was pressed and cut as above but aluminum foil was overlain on the right canine of the model so as to elevate the acrylic over that tooth. The occlusal surface was ground to force initial contact only on that tooth resulting in a deflection of the mandible to the right. Biting in the deflected position resulted in increasing the vertical

dimension approximately equal to the K-MORA. The device was identical to the K-MORA in every other respect with contacts distributed in approximately the same areas. After the device was equilibrated, a final, false IDP was administered to give the impression that the subject was "strong." The tester pushed down with little strength but by gestures and grimace gave the impression of "really pushing."

C. Placebo. Acrylic was cut halfway between the gingival margin and the top of each tooth to form the upper border and approximately 1 cm below the gingival margin to form the lower border. The device rested on the lingual aspect of the mandible and did not interfere with the usual bite of the subject. When the device was fitted intraorally, mock equilibration and testing with the IDP were performed as with the deflection device.

III. Determining Deltoid Strength under Different Bite Conditions

Subjects were exposed to two testing sequences on the first day and a third sequence one week later. Eight trials, each followed by a five-minute rest, occurred on the first day. The first two trials comprised sequence "A," the next six trials sequence "B." The following week, six trials biting in habitual comprised sequence "C."

Sequence "A"

One trial biting in either habitual or on the K-MORA (counterbalanced) followed in five minutes by the alternative.

Sequence "B"

Round 1:

D1: One trial with mandibular deflection device

P1: One trial with placebo

K1: One trial with K-MORA

Round 2:

D2: A second mandibular deflection trial

P2: A second placebo trial

K2: A final K-MORA trial

Sequence "C"

Six control trials with five minutes intervening, biting without devices to match, in sequence, trials in sequence "B."

These trials were designated DC1, PC1, KC1, DC2, PC2, and KC2.

A trial began when one experimenter placed the appliance in the subject's mouth and instructed him to bite while sustaining the weights as long as he could. Two other experimenters lowered the weights on the extended upper arms of the subject immediately after

[†]Dentsply acrylic—Dentsply International, York, Pennsylvania.

the word "ready." Another experimenter initiated recording the time two seconds after the word "ready." The trial ended when the color of the light changed and the timekeeper said the word "stop." At that moment, the two experimenters who applied the weight caught the arms of the device and relieved the weight.

Since it was unknown beforehand whether fatigue would be a factor, testing was intentionally biased against the K-MORA by placing it last in each round. The purpose of sequence "A" was to make a direct comparison between strength while biting habitually and on the K-MORA with minimal influence of fatigue. Sequence "C" was included to assess the effect of fatigue and to serve as control, providing a direct comparison, in sequence, with each experimental trial of sequence "B."

IV. Analysis of Data

A *t* test for repeated measures was performed on the two trials of sequence "A" to compare deltoid strength while biting on teeth and the K-MORA.

Repeated measures analysis of variance was performed on the data obtained from 35 subjects under the three experimental conditions to determine differences in strength while biting with the mandible in different positions. Data on fatigue were assessed by comparing means of round 1 (trials D1, P1, K1) with round 2 (trials D2, P2, K2).

Since only 23 subjects returned to provide measurements from the "C" sequence, data from these subjects were subjected to a separate, three-way factorial, within subjects design analysis of variance. Measurements from each experimental condition were matched in sequence with measurements of biting without an appliance, i.e., first deflection trial (D1) was matched with the first bite in the sequence without an appliance (DC1).

Results

The group means of time sustained in sequence "A" differed significantly ($t_{df,34} = 5.14, p < 0.001$). The same subjects biting on the K-MORA sustained significantly longer on the average ($X = 25.54, SD = 8.29$) than biting in habitual ($X = 18.62, SD = 8.81$).

Analysis of variance for repeated measures of the deflection, placebo, and K-MORA times for 35 Ss revealed a significant effect for conditions ($F_{df2,68} = 84.36, p < 0.0001$). Bartlett's test for equality of cell variances showed that the mean of the deflection trials, 13.46 seconds, $SD = 7.88$, was no different from the placebo mean, 13.31 seconds, $SD = 7.53$. The mean

of the K-MORA trials, 21.13 seconds, $SD = 7.95$, was significantly greater than either deflection or placebo ($p < 0.001$). Comparison of the means from round 1 versus round 2 of sequence "B" (round by condition interaction $F_{df2,68} = 0.44, p = 0.647$) revealed consistent levels of responding, providing no evidence of fatigue or learning between the first and second measurements of each condition.

The data from the 23 subjects who returned for the second day of testing were subjected to a second ANOVA (Table 1). The performance with the K-MORA was significantly greater than with either deflection or placebo ($F_{df2,44} = 35.58, p < 0.00001$). See Bartlett's Test of Table 1 and Figure 1. Examination of the contributions to the significant condition by sequence interaction ($F_{df2,44} = 47.49, p = 0.0001$) shows: (1) the significant sequence effect resulted from the reduction in the mean time from the K-MORA condition to the matched habitual control while there was little or no reduction in other conditions, (2) the K-MORA mean time was significantly greater than those of the other five conditions, and (3) the mean of the deflection control trials (D-control = 16.39 seconds) was significantly greater than the mean of the placebo trials (14.39 seconds). This difference was in the opposite direction (i.e., control greater than an experimental trial mean) from the consistent, multiple differences of the K-MORA mean from all other trial means. Analysis of variance revealed no significant difference between rounds in each condition (R \times C interaction). Figure 2 shows the consistency of the trial means in rounds 1 and 2.

Figure 3 presents the percent mean difference of matched K-MORA and habitual bite control trials. The same was done for placebo trials. For example, K1 and K2 were averaged, and this was compared with the mean of trials KC1 and KC2. Similarly, P1 and P2 were averaged and compared with the mean of trials PC1 and PC2. The percentage of difference for each subject is shown, rank ordered in magnitude of K-MORA response. Fourteen of 23 subjects showed at least a 50% increase over habitual bite control performance (subjects 10 to 23). Of these subjects, four showed at least 100% increase. One doubled and two almost quadrupled performance over control. Performance in the placebo condition showed as many increases as decreases in this measure while the K-MORA performance of 19 subjects showed an increase.

While reviewing individual data, it became apparent that the response of a minority of subjects was exceptional on the first trial of sequence "A." This first trial phenomenon is seen in the exceptional response

Table 1
Repeated Measures Analysis of Variance, 23 Ss 2 Rounds × 3 Conditions × 2 Sequences

Source	Sum of Squares	df	Mean Square	F	p
Mean	75921.82	1	75921.82	112.72	0.0000*
Error	14818.54	22	673.57		
Round	0.13	1	0.13	0.01	0.94
Error	552.64	22	25.12		
Condition	1013.61	2	505.80	35.58	0.0000*
Error	626.82	44	14.25		
R × C	20.41	2	10.20	0.97	0.39
Error	465.25	44	10.57		
Sequence	272.41	1	272.41	6.92	0.0152*
Error	865.57	22	39.34		
R × S	13.31	1	13.31	0.67	0.42
Error	439.02	22	19.96		
C × S	1320.93	2	660.46	47.49	0.0000*
Error	611.93	44	13.91		
R × C × S	11.00	2	5.50	0.50	0.61
Error	276.42	44	12.56		

*Significance at 0.05 level or smaller.

Bartlett's Test for Equality of Cell Variances
Condition by Sequence

Condition	Mean	Standard Deviation	N
Deflection (D)	15.02	8.70	46
D-Control (DC)	16.39	8.35	46
Placebo (P)	14.39	8.46	46
P-Control (PC)	15.23	8.61	46
K-MORA (K)	23.33	8.12	46
K-Control (KC)	15.16	7.94	46

	P	K	DC	PC	KC
D	NS	<0.001	NS	NS	NS
P		<0.001	<0.01	NS	NS
K			<0.001	<0.001	<0.001
DC				NS	NS
PC					NS

Paired Comparisons of Condition Means
Pairs Significantly Different Show Level

of subject S-3, **Figure 4** biting without an appliance. A response of similar magnitude does not appear in all other control, placebo, or deflection trials. Response with the K-MORA is reproduced consistently over trials. This phenomenon applies to the K-MORA as well. Subject B-1 (**Figure 5**) sustained 190 pounds for 41.1 seconds on the first trial of sequence "A" with the K-MORA. This level of response was not approached again by this subject regardless of the condition. In comparing **Figure 4** and **5**, the attention of the reader is directed to the time axis. Both subjects are matched at 190 pounds test weight. Eleven of the

35 subjects in the original group emitted such a response constituting 31% of the experimental population.

This phenomenon accounts for the inflation of the means in sequence "A" (K-MORA = 25.54, habitual = 18.62) opposed to the means of 35 subjects of sequence "B" (K-MORA = 21.13 and placebo = 13.31).

Discussion

In contradiction to previous speculation¹¹ concerning the role of placebo effect in isometric testing, this

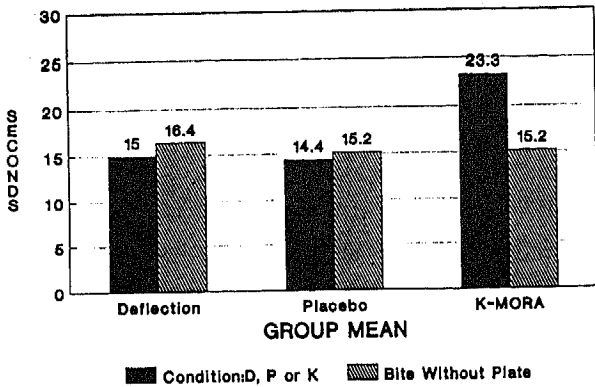


Figure 1 Group means based on 23 subjects tested twice in each condition.

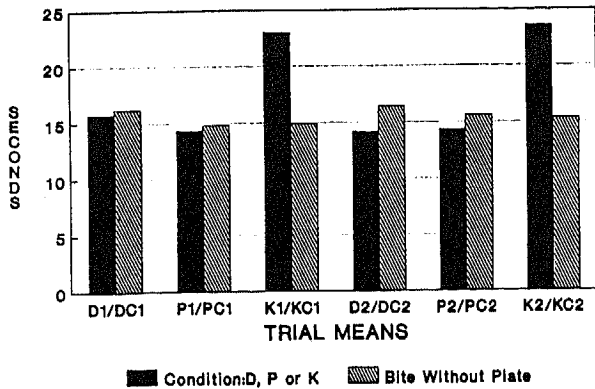


Figure 2 Individual trial means based on 23 subjects tested once in each trial.

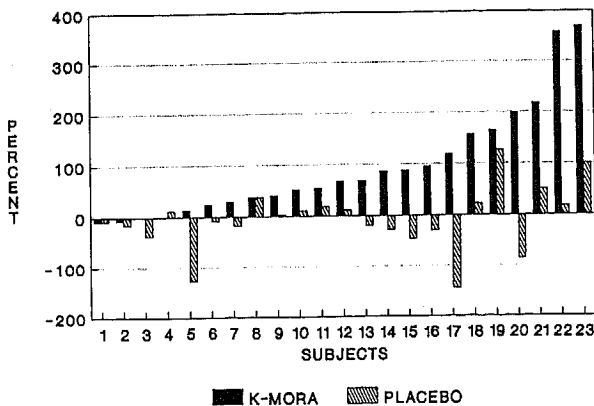


Figure 3 Mean percent difference from habitual bite control. Average time sustained for two K-MORA and two placebo trials compared with means of corresponding, time sequenced habitual bite control trials from Sequence "C." Individual data from 23 subjects arranged in ascending difference for K-MORA.

study found no evidence of the placebo effect. Isometric strength emitted in the K-MORA condition was found to be significantly greater than strength in all other conditions. Repeated testing in each condition produced responses in each condition that were consistent in the two rounds. The consistency is apparent in both the group means (Figure 2), the nonsignificant round by condition interaction in Table 1 and the graphs of individual responses (excluding the first trials). This result is in agreement with earlier studies^{3,4,10} and reports^{12,13} of an increase in isometric strength with the K-MORA. When combined with these earlier findings, the current data confirm a relationship between bite and strength of extraoral musculature. Fifteen subjects showed repeatedly at least a 50% increase in isometric strength over both placebo and deflection

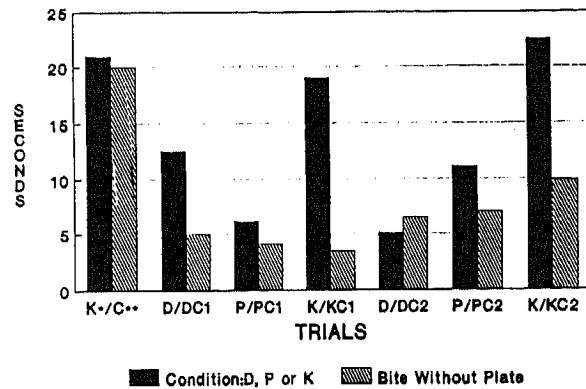


Figure 4 Individual performance of subject S-3 sustaining a weight of 190 pounds. Trial designated C** is the first trial of the experiment. Trial K* is the second trial of sequence "A."

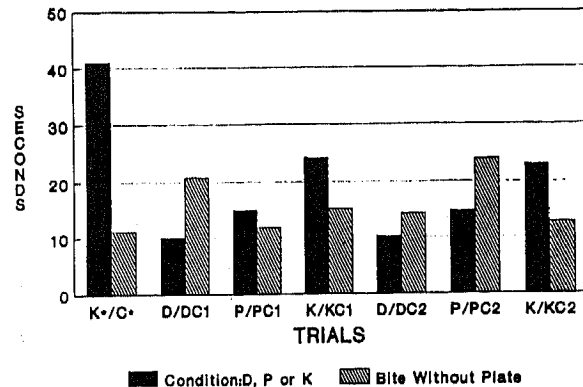


Figure 5 Individual performance of subject B-1 sustaining a weight of 190 pounds. Trial designated K* is the first trial of the experiment. Trial C* is the second trial of sequence "A."

performance. This number constitutes 43% of the 35 subjects who participated. Fourteen of the returning 23 subjects showed this performance. If the population of volunteers that participated in this study bears any similarity to the general population, the number of individuals that can increase isometric strength is great enough to merit serious consideration.

The IDP appears suited to identifying subjects who may demonstrate this increase. At present, the IDP is administered subjectively for both screening and guidance to fix mandibular position with the K-MORA. Concentrated research with a strain gauge may eventually refine and objectify this test. At present the response is an "either-or" response. What is needed is a method of measuring a gradation of response that is objective from zero "locking" to unyielding "lock." Crude as it may be and open to the criticism of subjectivity⁹ the current status of the subjective administration of the IDP is that it can guide the adjustment of a MORA to a position that enables the wearer to increase isometric strength reliably. The increase elevates performance to a level significantly greater than placebo, habitual bite or a deflection appliance that increases vertical dimension of occlusion to a similar height.

Most likely, the reason for the more salient effect of strength increase is because nonresponders to the IDP were excluded from the subject population. Subjects were not selected on the basis of malocclusion or TMJ symptomatology with purpose. A definitive criterion could not be created that would discriminate between the gradations in the continuum between normal occlusion and gross and obvious malocclusion even though the extremes could be identified easily. Distinctions in the majority of cases between these extremes are difficult to identify objectively. Therefore, the best control that could be exercised was to select subjects who were homogeneous with respect to a functional criterion, the IDP. Future research focusing on the degree of malocclusion necessary to elicit increased strength may well be assisted by studying only a homogeneous population of subjects who fail the IDP. In time, the innovative approach of Parker et al.⁹ may be applied to maloccluded subjects rather than normals or subjects who weaken to the IDP while biting. Their MORA fixed to a peak isokinetic strength criterion may produce significant difference from maloccluded bite and be related to isometric strength. The reverse order of testing may produce similar results. It appears logical that any MORA set to a functional criterion would increase performance to a greater degree than a MORA set to a therapeutic or dental-

structural criterion. This is not to say that some therapeutic or dental-structural MORAs do not approach the functionally determined position. The ideal therapeutic appliance would be a meld of dental-structural and functional criteria.

The increase in isometric strength associated with mandibular repositioning has therapeutic implications. Since maintaining posture is an isometric task, increasing the strength of postural muscles would be expected to decrease chronic muscle tension and strain levels. If cervical and head posturing muscles can be shown to react similarly to the deltoid muscles, the functional impact of a malpositioned bite and associated symptoms will be clarified.

The finding that deflection of the mandible at the elevated vertical dimension of the K-MORA resulted in strength no different from biting habitually or placebo also has research and therapeutic implications. Increase in vertical dimension alone is not sufficient to produce increased isometric strength. Establishment of the proper mandibular alignment in the lateral dimension appears to be the necessary condition to increase strength. Caution should be exercised in accepting results of experiments that do not adjust appliances to eliminate deflecting interferences *while the subject is postured in the test position*. Mehta and Forgione¹⁴ presented evidence that the bite changes dramatically with changes in upper body position.

A final methodological consideration stems from the observations of the first trial response. The potential for the first trial phenomenon to skew the data cautions against taking one measure in each condition. With randomized assignment to conditions this effect may be absorbed into the results of each condition unknowingly, resulting in a smaller difference between group means and increasing variances. This effect may account, in part, for the significant condition by sequence interaction in the second ANOVA of this experiment. The deflection control trial was the first in sequence "C" and the first trial of the last day of the experiment. This finding suggests that the first two trials of the experimental day be recorded but not included in the main analysis.

Since the majority of research has been performed on athletes, it must be mentioned in closing, that these findings have broader application. In certain vocations it may well be a matter of personal safety. Police, firemen, nurses, paramedics, and movers need to maintain strong muscle contractions for extended periods. Even the average sedentary maloccluded individual who is not well conditioned may be at risk of muscle strain or injury if required to maintain con-

tractions for extended periods in an occasional strenuous task.

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