Evaluation of Peak Force of a Manually Operated Chiropractic Adjusting Instrument With an Adapter for Use in Animals

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Abstract

Objective: This study was designed to assess the peak force of a manually operated chiropractic adjusting instrument, the Activator Adjusting Instrument 4 (AAI 4), with an adapter for use in animals, which has a 3- to 4-fold smaller contact surface area than the original rubber tip.

Methods: Peak force was determined by thrusting the AAI 4 with the adapter or the original rubber tip onto a load cell. First, the AAI 4 was applied perpendicularly by a doctor of chiropractic onto the load cell. Then, the AAI 4 was fixed in a rigid framework and applied to the load cell. This procedure was done to prevent any load on the load cell before the thrust impulse. In 2 situations, trials were performed with the AAI 4 at all force settings (settings I, II, III, and IV, minimum to maximum, respectively). A total of 50 000 samples per second over a period of 3 seconds were collected.

Results: In 2 experimental protocols, the use of the adapter in the AAI 4 increased the peak force only with setting I. The new value was around 80% of the maximum value found for the AAI 4. Nevertheless, the peak force values of the AAI 4 with the adapter and with the original rubber tip in setting IV were similar.

Conclusion: The adapter effectively determines the maximum peak force value at force setting I of AAI 4. (J Manipulative Physiol Ther 2014;xx:1-6)

Key Indexing Terms: *Chiropractic; Biomechanics; Manipulation, Spinal*

The use of chiropractic methods for treatment and prevention of changes in the musculoskeletal system has been increasing worldwide.[1-6] In chiropractic, there is an emphasis on manual treatments, such as vertebral manipulation with high velocity and low amplitude. However, techniques involving the use of instruments are also used, particularly the Activator Adjusting Instrument (AAI), a hand-operated device for applying mechanical force.[7-10] Although several mechanical instruments to apply force exist, the Activator Adjusting Instrument 4 (AAI 4) is considered to be the most popular of these instruments.[11]

The AAI 4 is a hand-operated and spring-loaded device designed for clinical use in human patients. This device is used for treating functional changes affecting the spinal column and other joints. It delivers a mechanical force or thrust to a patient's spine at a rapid speed and in a precise direction.[7-10,12-17] Of the 5 existing versions of the AAI, we

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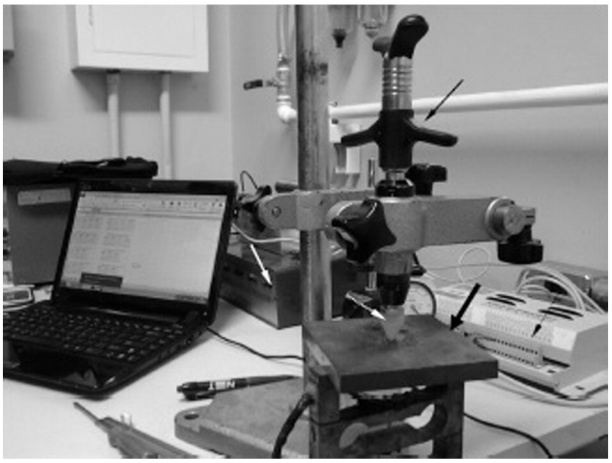

Fig 1. *Activator Adjusting Instrument 4 (narrow black arrow) with adapter (narrow white dotted arrow) attached rigidly to a framework that maintains the same position when thrusting. Note the load cell (wide black arrow), the converter (narrow black dotted arrow), and the signal conditioner (narrow white arrow) used to detect the peak force of the AAI 4 when this device was manually held and held by a fixed rigid arm.*

used the fourth, the AAI 4 (Fig 1). This device possesses 4 (I, II, III, and IV) precision force settings, where I corresponds to the minimum force and IV to the maximum force. One advantage of its use is the application of a controlled force with less variability compared with vertebral manipulation.[8,9,11] Thus, the AAI may offer an advantage over manual adjustments for research studies that aim to demonstrate the physiological responses to high-velocity, very-low-amplitude thrusts.

Historically, animal models have been used experimentally to improve the understanding of several disorders such as cancer, diabetes mellitus, high blood pressure, and others as well as in research to develop new forms of treatment for a number of pathologic conditions.[18-21] The use of animal models in chiropractic has been growing and will certainly result in better understanding of the inherent mechanisms of the chiropractic treatment.[22-26] Animal models have also been used in studies that aim to demonstrate the physiological effects of the AAI.[5,13,27-29] A recent study showed that the use of AAI 4 improved mechanical sensitivity after immobilization of the right hind paw in rats.[30] However, this study used an adapter placed at the end of the AAI 4 that reduced the contact surface area of the device by around 4-fold.[30] The contact area was reduced because the rat has a mass approximately 350× smaller than a human weighing 70 kg. Nevertheless, the force exerted by the AAI 4 was concentrated in the small area of the adapter. It is possible that the force of the AAI 4 onto the animal was of greater magnitude.

Therefore, this study was designed to assess the peak force of a manually operated chiropractic adjusting instrument, the AAI 4, with an adapter for use in animals, which has a 3- to 4-fold smaller contact surface area than the original rubber tip.

Fig 2. *Adapter of the AAI 4 developed for use in studies with animal models, which was used in AAI 4 that was manually held and held by a fixed rigid arm.*

Methods

This study used a load cell to assess the peak force of the AAI 4 with an adapter and with the original rubber tip. First, the AAI 4 was applied perpendicularly by a doctor of chiropractic (DC) onto the load cell. Then, the AAI 4 was fixed in a rigid metal arm and applied perpendicularly onto the load cell. This last experimental step was carried out to prevent the effect of any load on the load cell before the thrust impulse. In 2 experimental protocols, the peak force of the AAI 4 was determined in its 4 force settings.

Experimental Procedures

The investigation was carried out using the AAI 4 manufactured by Activator Methods International, Ltd (Phoenix, AZ). In the tests, the peak force values of the AAI 4 were determined at each of its force levels (I, II, III, and IV), with 2 different tips. The original tip was manufactured of silicone polymer, with a contact surface area of about 0.785 cm^2. The adapter (a gift from Trierweiler et al[30]—the same used in their study) (Figs 1 and 2) was made of nylon, with a contact surface area one-fourth of the original (0.196 cm^2), and has 25% of the total area of the original tip.

For determination of peak force values, we used a load cell of the "S" type, with 30 kgf capacity (Fig 1), manufactured by the Grupo de Mecânica Aplicada (Department of Mechanical Engineering, School of Engineering, Federal University of Rio Grande do Sul, Brazil).

For the tests, the load cell was mounted rigidly on a table, and the AAI 4 was thrust perpendicularly onto it (Fig 1). Data for the load cell were collected by a 16-bit analog converter (USB1608HS2AO; Measurement Computing, Norton, MA) connected to a signal conditioner with 5 inputs (manufactured

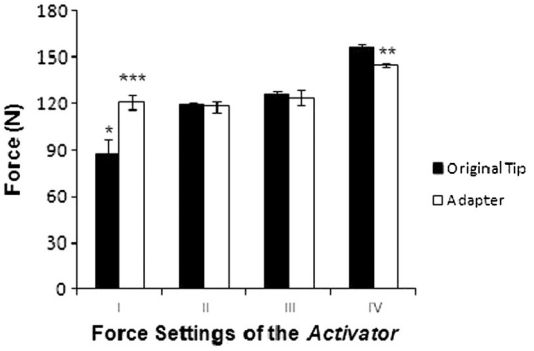

Fig 3. *Mean peak force of the AAI 4 with adapter and original rubber tip at all force settings (I, II, II, and IV) when the device was manually applied by a doctor of chiropractic on the load cell. Data represent the means ± SEM. * indicates significant difference when force setting I is compared with other force settings of the AAI 4 with original rubber tip; **, significant difference when force setting IV is compared with force settings I of the AAI 4 with adapter; ***, significant difference when force setting I is compared between AAI 4 with adapter and original rubber tip (2-way ANOVA followed by Tukey post hoc test, P < .05).*

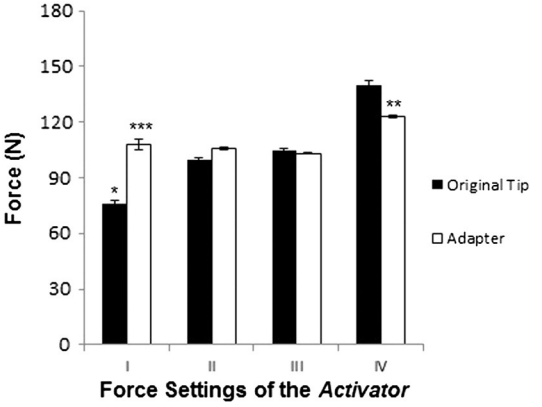

Fig 4. *Mean peak force of the AAI 4 with adapter and original rubber tip at all force settings (I, II, II, and IV) when the device was fixed in a rigid framework and applied to the load cell. Data represent the means ± SEM. * indicates significant difference when force setting I is compared with other force settings of the AAI 4 with original rubber tip; **, significant difference when force setting IV is compared with force settings I of the AAI 4 with adapter; ***, significant difference when force setting I is compared between AAI 4 with adapter and with original rubber tip (2-way ANOVA followed by Tukey post hoc test, P < .05).*

by the Grupo de Mecânica Aplicada). This device was connected to a current amplifier (Model TL074; Texas Instruments, Inc, Dallas, TX), which, in turn, was connected to a computer. Data were analyzed using Agilent software (UEE Pro 7.5; Agilent Technology, CA).

Peak force determinations were carried out in 2 experimental protocols. First, a DC applied a perpendicular uniaxial force to the load cell. Then, the AAI 4 was attached perpendicularly to a rigid metal arm, and a uniaxial force was applied to the load cell.

In 2 experimental protocols, the peak force was determined by thrusting the AAI 4 onto the load cell 3 times consecutively, with 10-second intervals between each application. With these procedures, the peak force was determined at each force setting of the AAI 4, with the adapter and the original tip. In each of these tests and at each of the AAI 4 force levels, 50 000 points per second were collected for 3 seconds.

Statistical Analysis

Data were compared by 2-way analysis of variance (ANOVA) followed by the Tukey post hoc test. Differences were considered statistically significant when the *P* value was less than .05. All statistical analyses were carried out with Sigma Stat 3.5 software (Systat Software, San Jose, CA).

Results

The use of the adapter changed the peak force values in the AAI 4. When the AAI 4 with the adapter was applied manually by the DC, the peak force value was 121 N at setting I, whereas with the original rubber tip, it was 87 N (Fig 3). The value found with the adapter was 39% higher than that with the original rubber tip. No significant change was found in the peak force with the adapter at force settings II and III compared with force setting I. However, the peak force increased approximately 20% with the adapter at force setting IV compared with setting I. The peak force value with the adapter at force setting IV was 145 N, whereas with the original rubber tip, it was 156 N. The difference was not statistically significant.

The use of the adapter also increased the peak force at setting I when the AAI 4 was rigidly fixed by the framework (Fig 4). The changes were similar to that found when AAI 4 with the adapter and original tip was applied manually by the DC. The new values were as follows: with adapter (I, 108 N; II, 106 N; III, 103 N; IV, 123 N); original rubber tip (I, 76 N; II, 100 N; III, 105 N; IV, 140 N). Thus, the peak force of the AAI 4 with adapter at force setting I was approximately 80% of the maximum value developed by the device. The peak force changed around 20% from the minimum to maximum settings of the AAI 4 when the adapter was used, whereas the peak force of this device with the original rubber tip had a gradual increment from the minimum to maximum force settings.

Discussion

The data obtained show that the use of the adapter on the AAI 4 increased the peak force only at setting I in 2 experimental protocols. The new value at this force setting was around 80% of the peak force at setting IV of the AAI 4. No significant change occurred at force settings II and III of the AAI 4 with the adapter. At these force settings, the

values were similar to those found for the AAI 4 with the original rubber tip. Nevertheless, the peak force values of the AAI 4 with adapter and original rubber tip in setting IV were similar. Therefore, the use of the adapter increases the peak force only at setting I of the AAI 4. As the peak force is already elevated at setting I, the peak force changes less from the minimum to maximum force setting when the adapter is used. This appears to be a characteristic response of the AAI 4 with the adapter. In the 2 protocols studied here, the adapter induced an increase in peak force only at setting I of the AAI 4. Therefore, the adapter practically determines the maximal peak force value at setting I of AAI 4. Nevertheless, the maximum force achieved is similar to that obtained at force setting IV with the original rubber tip.

The gradual shift in peak force values of the AAI 4 from minimum to maximum force settings when the original rubber tip was used also occurred in other studies.[11,16,31] Thus, our results with the original tip reproduced those in the literature. This reinforces the possibility that the changes in the peak force values of the AAI 4 with the adapter are due to the use of the adapter. Because the adapter reduced around 4-fold the contact surface area of the AAI 4, the energy from the large area of the AAI 4 was concentrated in this smaller area (which corresponds to 25% of the original rubber tip area). It is, therefore, possible that the increase in peak force of the AAI 4 with the adapter is related to the reduction of the contact surface area of the AAI 4. Supporting this hypothesis is the similar increase in the peak force at setting I of the AAI 4 with the adapter in the 2 protocols used here, where the AAI 4 was held manually by a DC or held in a rigidly fixed metal arm. Because, in this latter condition, only the force delivered by the AAI 4 was assessed, this result reinforces the role of the tip in affecting the peak force of the AAI 4.

However, it is impossible to exclude a possible effect on the peak force of the material used to manufacture the adapter. The adapter was made of nylon, whereas the original rubber tip was made of silicone. Further studies with adapters fabricated with other materials, including silicone, are necessary to clarify the effects of the material types on the peak force of the AAI 4 with the adapter.

Interestingly, the use of the AAI 4 with the adapter improved the sensitivity after immobilization of the right hind paw in the rat.[30] It is possible that the increase in peak force of the AAI 4 with the adapter contributed to this effect. However, it was demonstrated that a force of 40 N is enough to activate mechanoreceptive afferents deemed appropriate in neuromuscular reflexes.[32] According to Trierweiler et al,[30] the Von Frey filament test was performed immediately after chiropractic manipulation of the immobilized rats. The Von Frey test creates a mechanical stimulus that triggers a light and constant pressure required to cause withdrawal of the hind paw.[30,33] The magnitude of the force necessary to induce this response is around 40 N.[32] Thus, the force developed by the AAI 4 with the adapter was sufficient to activate the withdrawal response of the rats. Another study reported that treatment with AAI 3 (another model of mechanical force, manually assisted chiropractic adjusting instrument), with the original rubber tip, not only reduced mechanical and thermal sensitivity but also caused a decrease in inflammatory parameters in rats submitted to a painful condition.[25] Thus, it is possible that the reduction in inflammatory parameters may have contributed to the antinociceptive response of the immobilized rats that were treated with the AAI 4 with adapter.[30] It is presently impossible to discard this hypothesis because the magnitude of the peak force of the AAI 4 with the original rubber tip in our study was similar to that generated by the AAI 3.[16] In addition, it is necessary to consider the compliance (stiffness) of the rat tissue and the response of this tissue to input force (impedance). It is impossible to determine the effect of the increase in peak force of the AAI 4 with the adapter on these parameters. It has been suggested that the natural resonance frequency, tissue compliance, response to input force, and comparisons to other types of adjustment should be areas of inquiry for AAI research.[5] Further studies are necessary to clarify the mechanisms involved in the antinociceptive effect of the AAI 4 with the adapter on rats.

Although the AAI 4 with the adapter can be a useful tool to study the effects of chiropractic treatment in animal models, its ultimate scientific validation requires more testing using different approaches.[33] Our results are important because they are the first to demonstrate that the use of the adapter in the AAI 4 practically determines the maximal peak force value at force setting I of this device, but the maximum force achieved is similar to that obtained at force setting IV with the original rubber tip.

Limitations

There are some limitations that should be considered for this study. It is necessary to obtain more details about the peak force delivery by the AAI 4 with adapter. Studies using more-precise devices, that is, transducers, are necessary. In addition, studies with adapters developed with other materials are needed to show the influence of the material on the peak force of the AAI 4. Because animal models have lower mass than humans, it would be appropriate to determine the effects of the force delivered by the AAI 4 with the adapter on the animal tissues.

Conclusion

In the 2 experimental protocols, where AAI 4 was manually held by a DC or held in a rigidly fixed metal arm and applied onto the load cell, the use of an adapter at the end of the AAI 4 (which reduced the contact surface area 4-fold) increased the peak force only at setting I. Because the new value was around 80% of the peak force found at setting IV of the AAI 4, the adapter practically determines the maximal peak force value at setting I.

Practical Applications

- Peak force of Activator increases with adapter for use in animal models.
- Future studies with AAI 4 with adapter must take into account the increase in peak force.
- The adapter practically determines the maximum peak force value at force setting I of AAI 4.

Funding Sources and Potential Conflicts of Interest

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Contributorship Information

Concept development (provided idea for the research): FCKD, CK, RRB, VGAS, JMV, WAP

Design (planned the methods to generate the results): FCKD, CK, RRB, GG, JMV, WAP

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): FCKD, JMV, WAP

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): FCKD, RRB, JMV, WAP

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): FCKD, WAP

Literature search (performed the literature search): FCKD, WAP

Writing (responsible for writing a substantive part of the manuscript): FCKD, WAP

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): CK, WAP

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