Whole Body Vibration Increases Area and Stiffness of the Flexor Carpi Ulnaris Tendon in the Rat

INTRODUCTION:
Whole body vibration has been shown to help preserve or increase bone volume, bone density, and bone mechanical properties in both animal and human studies. Furthermore, whole body vibration has also been shown to help preserve or increase muscle cross-sectional area and muscle strength in both animal and human studies. In considering these findings, it would seem plausible that whole body vibration may also have effects on tendon. However, there has been apparently only one study that has examined the possible effects of whole body vibration on tendon, and it showed no effect though the daily duration of vibration exposure used was quite limited in this study. The objective of our study was to determine the effects of high frequency, low magnitude whole body vibration on the structural and material properties of the dominant wrist flexor tendon of the rat, the flexor carpi ulnaris tendon. It was hypothesized that an increase in tendon cross-sectional area and structural properties would occur with vibration exposure.

METHODS:
After approval by the UNC IACUC, a total of 30 animals were randomly assigned to 2 groups: control or 0.15G (Peak) vibration at 30Hz. All animals were part of a fracture healing study and underwent a surgery to create a transverse osteotomy of the middle third of the right tibia and a stainless steel intramedullary pin was used for fracture stabilization. Vibration stimulation began on postop day 5 for 20min/day for 5d/wk until sacrifice at 5weeks. Rats were subjected to whole body vibration on a 4 chamber vibration platform interfaced with an electromagnetic shaker. Controls animals were also moved to the platform, but left unstimulated. All animals were sacrificed 35 days after their initial surgery and the forelimbs were harvested. The flexor carpi ulnaris muscle-tendon unit was dissected free from surrounding tissues leaving the distal insertion of the tendon on the pisiform, hamate, and 5th metacarpal bones were left intact. The dissected tissues were wrapped in saline-soaked gauze and stored at -20°C until the day of mechanical testing. The cross-sectional area of the tendon was measured at a location 8mm from the distal insertion by means of an area micrometer under a compressive pressure of 0.12MPa. Area measurements were done in triplicate and averaged.

Tensile testing of the muscle-tendon-bone unit was carried out on a materials testing system using two cryogrips that allowed liquid nitrogen to circulate thru the interior of the grip. In one grip the muscle belly was gripped so that myotendinous junction was at the external grip edge and for the other grip the forepaw was placed in the grip so that the insertion was at the grip edge. Each tendon was pretensioned with a 0.5N of load and the grip gauge length was measured with digital calipers. The specimen was then preconditioned for 10 cycles of 0.5Hz haversine loading to 2% strain followed by ramp loading at approximately 1% strain/second until failure. Both structural and material properties were determined from the force-deformation data. Mode of failure was recorded and any specimens failing at the myotendinous junction were discarded from statistical analysis. A Student’s t-test was used to determine statistical differences in the mass, geometric, and structural properties between the groups (P<0.05). The frequency of midsubstance versus insertion failures between the groups was analyzed by Fishers Exact Test.

RESULTS:
Initial body weights were similar between the groups and the mean change in body weight of the animals of each group did not differ. The gauge length of the tendons of each group were not found to differ. The cross-sectional area of the tendons of the vibrated animals was found to be 32% greater (P<0.05) than that of the control animals (Fig. 1). The structural stiffness of the vibrated tendons was found to be 41% greater (P<0.05) than that of the control tendons (Fig. 2). The displacement and strain at ultimate load were found to be significantly less for the vibrated group (P<0.05), while the remaining properties did not differ between the groups (Table 1). The frequency of failure types in the groups was equivalent between the groups with there being 5 insertion failures, 9 midsubstance failures, and 1 myotendinous junction failure in each group. When the ultimate load of solely the midsubstance failures was analyzed for statistical differences, a trend (P=0.087) for increased load was present for the vibrated tendons (control: 32.3N, vib: 37.5N).

Table 1: Structural and Material Properties of Tendon-Bone Unit

<table>
<thead>
<tr>
<th>Group</th>
<th>Ult Load (N)</th>
<th>Ult Stress (MPa)</th>
<th>Disp at Ult (mm)</th>
<th>Elastic Modulus (GPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>33.6± 6.6</td>
<td>131.8± 52.2</td>
<td>2.47±0.59</td>
<td>1.17±0.56</td>
</tr>
<tr>
<td>vib</td>
<td>37.5± 6.8</td>
<td>105.1± 25.0</td>
<td>1.95±0.52*</td>
<td>1.28±0.52</td>
</tr>
</tbody>
</table>

* Significant Difference (P<0.05)

DISCUSSION: Our findings suggested that vibration can serve as an anabolic stimulus to tendon similar to its effects on bone and muscle. The altered structural properties would appear to be directly related to the increased area found in the vibrated tendons as the material properties were not found to change. While an increase in structural strength was not detected with this increased area, the failures at the tendon insertion may have limited our ability to detect such an improvement. This initial study is limited in that all animals were part of a fracture healing study in which their right tibia was fractured and stabilized. All animals were found to visually return to full weight bearing on all limbs by postoperative day 5 when the vibration stimulation began. With these initial positive findings, future work will have to determine if vibration can serve as an anabolic stimulus to tendon healing after injury similar to its acceleration of fracture healing(1).


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Fig. 1. Tendon cross-sectional area is 32% greater (+P<0.05) in vibrated animals.

Fig. 2. Tendon stiffness is 41% greater (+P<0.05) in vibrated animals.

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