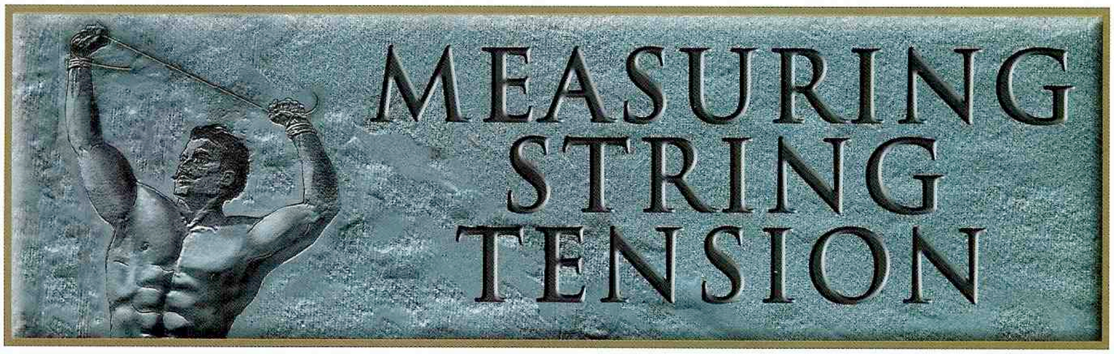


How To Measure String Tension and What It Means: Part 2

Rod Cross

(Editor's note: Part 1 of this article appeared last month in the June RacquetTECH Magazine)

String Tension: Can Players Still Tell the Difference?

A few months ago, Rob Bower (Lecturer in Sport Science at the University of Technology, Sydney, Australia) and I strung five identical Volkl Pro Comp racquets all with the same string but at five different tensions. We wanted to see how well players could pick the differences in tension just by hitting a ball a few times with each racquet. They were instructed not to hit the strings with their hand or with another racquet since the differences in the sound are easy to pick. A string dampener was inserted in each racquet to deaden the sound, since we wanted the players to pick the differences in the feel or performance, not the differences in the sound. After testing 41 different players it became obvious that they were not very good at picking differences. More than half of them could not pick a difference of 15 lb. We then tested 18 professional satellite players at a tournament in Sydney. For them, we used four identical Topspin 630 Pro racquets, all a bit heavier than the Volkl racquets and more suited to their game. They were not much better than anyone else at picking the tensions. Eleven of the 18 satellite players could not pick a difference of 11 lb, even though most of them specify the tension to the nearest lb when stringing their racquets.

Though many accomplished players can't pick small differences in string tension, a small minority can. The above players were not asked to identify specific tension, just to choose which was strung looser or tighter than the other. In the process of doing the experiment we had to measure tension in many different ways – reference tension, pull tension during stringing, stringbed stiffness (not tension) after stringing, actual average stringbed tension (not stiffness) after stringing, actual individual string tensions after stringing, and perceptual tension, which was what the experiment was all about. These are all different concepts but very frequently used interchangeably, lumped into one, and referred to simply as "string tension." To add to the confusion, the available methods to determine these things use different calibrations and measure different parameters, yet often use the same vocabulary. Figuring out what we were measuring was important to our test, but it is also important to the stringer. It is important to know what each device is actually measuring and how it is useful to you. The main thing we discovered is that all the devices do a good job measuring relative changes in racquet tension, but actual tension was much harder to pin down. Fortunately, once the racquet is strung, stringers and players are primarily interested in relative tension changes, not absolute measurements. Unfortunately, many are not aware that is what they are doing.

Determining Actual Stringbed Tension: Method 1

The main thing we needed to be sure about in our experiment was the string tension. The stringing machines were accurately calibrated against a load cell to make sure the pull tension was correct, and exactly the same procedure was used to string each racquet. At the time, we didn't have a Stringmeter or an ERT700 or a portable racquet diagnostic machine, so I invented my own way of measuring the tension at regular intervals before the playtests and afterwards, to make sure the differences in tension stayed about the same as when the racquets were first strung. For that purpose a small piezo was attached to the strings to measure the vibration frequency of the strings. That was enough to show me that the strings at high tension vibrated at a higher frequency (as I could hear with my own ears) and that the relative differences in the tensions were correctly maintained throughout the tests. The tensions all dropped slightly over a few days, but not enough to worry about.

Determining Actual Stringbed Tension: Method 2

After the tests were over, I discovered a simple formula (published in the Stringer's Assistant in September, 1990, page 18 by Howard Brody) that would allow me to calculate the actual tensions from the vibration frequencies. Using that formula, I then discovered that the tensions were a lot lower than the pull tensions. I wasn't totally surprised because the tests I did with Crawford Lindsey last year (Racquet Tech, June 2000) showed that all strings drop rapidly in tension after clamping. Nylon strings drop by about 9 lb in just 17 minutes, which is about the time it takes to string a racquet. My tension results were even lower than that, so I checked the measurements using a microphone to record the sound of

continued on page 16

continued from page 14

the vibrating strings. This time the frequencies and hence the tensions were slightly higher than I found with the piezo. The problem with the piezo was that it weighed 2.2 gm, a lot less than the 15 or 16 gm weight of the strings, but enough to lower the vibration frequency by about 15%. Even so, the tensions were all about 30% lower than the pull tensions in all of the racquets, immediately after stringing them. For example, the racquet strung at 60 lb was actually at a tension of about 42 lb. But still, was the frequency determined tension correct? The frequency calculation gives an average stringbed tension. How does that compare to the tensions in individual strings?

Determining Tension in Each String

In order to investigate further, I set up the arrangement shown in figure 1.

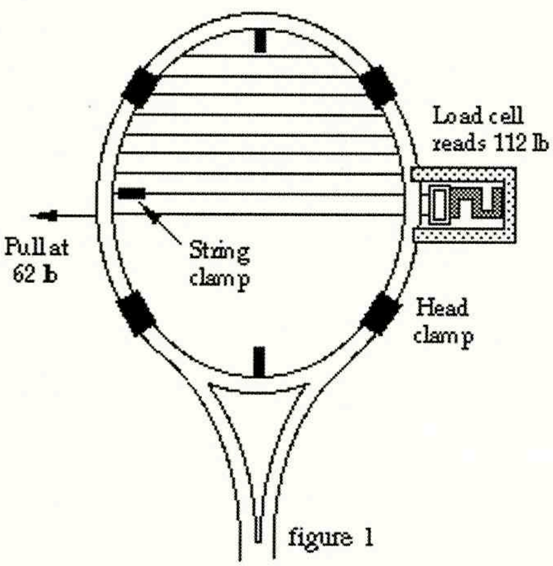


figure 1

A metal bracket was made up so that it could be attached at the 3 o'clock position together with a load cell to measure the tension in two of the cross strings. For this experiment I used a 1.30 mm diameter polyester string. After stringing the mains, the first seven cross strings were installed and the 8th and 9th strings were threaded through a small bracket attached to the load cell. Each string was tensioned to 62 lb. However, the reading on the load cell was then 112 lb. It should have been 2 x 62 = 124 lb since two strings each at 62 lb were pulling on the load cell. The alignment of the pulling head, together with friction in the grommet holes and friction between the mains and crosses all acted to reduce the tension from 124 to 112 lb. As each additional cross string was added, the reading on the load cell dropped further due to contraction of the frame. The frame was actually supported at 10 points in a Pacific stringing machine, but that was still not enough to prevent the frame contracting slightly. By the time the job was completed, and on removal of the racquet from the stringing machine, the load cell reading had dropped to 76 lb, or an average of 38 lb in each cross string. The tension in the main strings was not measured due to restricted access near the 12 o'clock position. So here was a baseline actual tension against which to compare both theoretical calculations and tension testing equipment.

Comaring Pull Tension, ERT, Pacific RA, and Calculations

Results similar to mine have been obtained before by Dr Carl Love (Racquet Tech, March 2001 and April 1998). His results and mine seem to be at odds with the folklore that the tension immediately after stringing a racquet might be a few pounds lower than the pull tension, but not much more than that. So I bought a Stringmeter and an ERT700 (see June Racquet Tech for Part I of this article) to see what they said compared to my calculations using frequencies determined with a microphone. The results of the various tests are given in the tables below. Some of the tests were done immediately after stringing and some were done a few months later on the same racquets, which were put aside and not used during that time. Pull T is the pull tension, TP is the tension indicated in a Pacific racquet diagnostic machine, f (Hz) is the vibration frequency of the strings measured with a microphone, TVib is the tension calculated from the vibration frequency of the strings, ERT is the tension indicated by the ERT700

The results in tables 1 and 2 show that the Pacific diagnostic machine and the ERT700 give tensions that are similar to the pull tensions, but the tensions calculated from the vibration frequencies of the strings are much lower and are more consistent with the measurements made using the arrangement shown in Fig. 1. The vibration frequencies for the Topspin racquets were generally higher than those for

Table 1. Volkl racquets immediately after stringing with 1.42 mm nylon

Racquet	Pull T (lb)	TP (lb)	f (Hz)	TVib (lb)
Volkl 1	39.7	46.3	504	26.7
Volkl 2	46.3	50.7	549	31.7
Volkl 3	50.7	52.9	565	33.5
Volkl 4	55.6	55.1	599	37.7
Volkl 5	62.6	58.4	645	43.6

Table 2. Topspin racquets immediately after stringing with 1.27 mm nylon

Racquet	Pull T (lb)	ERT	f (Hz)	TVib (lb)
Topspin 1	46.3	50.7	632	32.8
Topspin 2	52.9	52.9	653	35.0
Topspin 3	57.3	57.3	695	39.7
Topspin 4	63.9	63.9	724	43.2

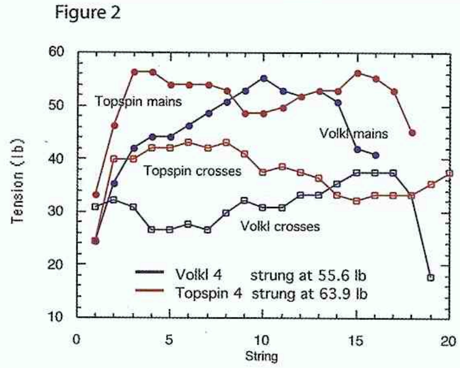
the Volkl racquets, even though both models had exactly the same head size at 630 cm2 (98 in2). The difference in frequency is due to the smaller diameter and lighter string used in the Topspin racquets.

Comparing the Stringmeter with Calculations

The Volkl racquets were strung on 30th Nov 2000. The Topspin racquets were strung on 8th Feb 2001. The racquets were put aside after testing the players, and on 11th March 2001, the tension in every string was measured using a Stringmeter. I also re-measured the vibration frequencies of the strings. The results for racquets Volkl 4 and Topspin 4 are shown in Fig. 2.

In both cases, the tension in the cross strings was much less than the tension in the mains, a result that can be explained by the fact that the tensions in the cross strings drop and the tensions in the mains increase due to contraction of the frame when the crosses are installed. The Topspin 4 frequency had dropped to 655 Hz, giving an average stringbed tension of 35.3 lb. The Volkl 4 frequency had dropped to 558 Hz, giving an average stringbed tension of 32.6 lb. These tensions correspond roughly to the average tension in the cross strings rather than the average tension in the mains if one can believe the Stringmeter readings shown in Fig. 2. Theoretically, one would expect that the vibration frequency of the strings should be determined by the average tension of all the strings, not just the cross strings. Consequently, I decided that either the Stringmeter readings were too high or the tensions deduced from the string vibration frequencies were too low.

Figure 2



Where Do I Go From Here?

The ERT700 also uses a measurement of the vibration frequency of the strings to determine the average string tension. On 11th March, the ERT700 readings were 50.7 lb for the Topspin 4 racquet and 48.5 lb for the Volkl 4 racquet. These tensions are close to the average Stringmeter tension in the main strings rather than the cross strings, and appear to be too high since the results in Table 2 indicate that the ERT700 is calibrated to read the pull tension when a racquet is freshly strung. All three methods of measuring the string tension indicated that the tension dropped in all

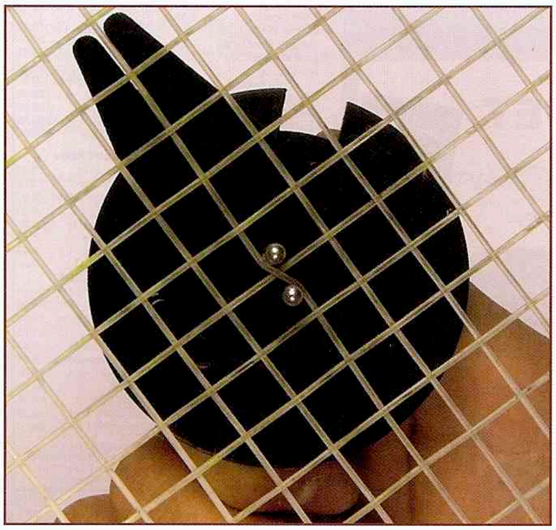
continued on page 18

continued from page 17

racquets during the period after they were strung, but the actual tensions were proving hard to pin down.

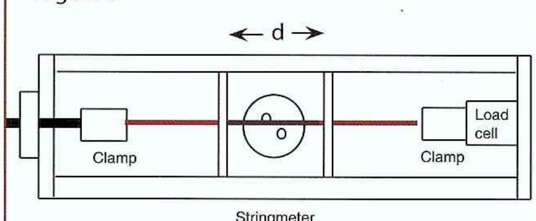
The Stringmeter

When a Stringmeter is used to measure the tension in a string, two prongs are positioned either side of the string then the prongs are rotated to twist the string sideways (see photo).



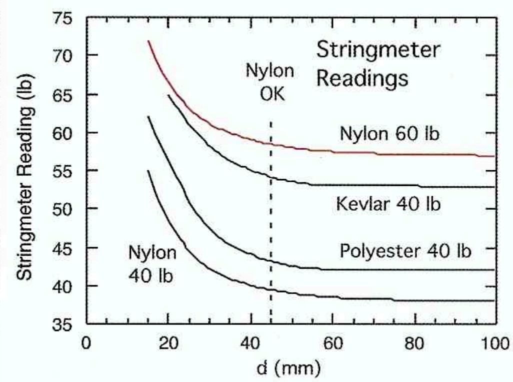
Most of the length of the string is locked into position by the other strings, but a small section of the string about 1 inch long gets stretched and twisted, especially in the section about 1/2 inch long surrounding the two prongs. If a single long string is tested this way, the Stringmeter reading is lower than the actual tension since a smaller force is needed to twist a long string than a short string. That is why a separate scale is provided on the Stringmeter to test single strings. Furthermore, a much larger force is needed to twist a stiff string than a soft string. If one tests a steel wire under tension with a Stringmeter, the reading on the Stringmeter is much higher than the actual tension.
Apparatus was set up to test the Stringmeter as shown in Fig. 3.

Figure 3



A single string about 14 inches long was tensioned to either 40 or 60 lb, as indicated on an accurate load cell. Two short parallel bars, each perpendicular to the string, were positioned a distance d apart so that the string passed through a small hole in each bar. A Stringmeter was then used to measure the tension in the string between the bars as the distance d was varied from 150 mm down to 15 mm. The sideways movement of the string was thereby restricted to only a short section of the string of length d.

Figure 4



As shown in Fig. 4, the Stringmeter reading increased as d decreased. At large d the reading for a nylon string was smaller than the actual tension, but for a kevlar string, the reading was larger than the actual tension. At a distanced about 40 to 50 mm, corresponding to the actual distance over which the string is twisted in a racquet, the Stringmeter reading was almost spot-on for the nylon string, but was way too high for a kevlar string.

Conclusion

My conclusion is that the old-fashioned Stringmeter is still the best instrument available to measure actual string tension, provided that it is only used on relatively soft strings such as nylon and natural gut, and provided that that is what is useful to you. But at the same time, it is more difficult to determine what has happened to the entire stringbed.

The other methods also indicate whether the tension in a racquet has dropped, and roughly by how much, but the actual values are not correct. The ERT700 and racquet diagnostic devices read too high and my own string vibration measurement reads too low for reasons that I have not yet been able to figure out.

All the devices are good at telling relative differences in a racquet over time or between two racquets. As long as you understand what each device is telling you, and how each differs from the other, then you will be able to make intelligent decisions when it comes to stringing tensions. ■