TENNIS ARM INJURY EPIDEMIC

Two-time Grand Slam finalist Vera Zvonareva is recovering from shoulder surgery. (Facebook)

Vera Zvonareva had surgery on her right shoulder this week and won't return for several months

THE ARM INJURY EPIDEMIC

8 OUT OF 10 TOP PLAYERS SUFFER MULTIPLE ARM INJURIES OR SURGERIES: [1]

34 OF TOP 40 ATP AND WTA PROS SUFFERED RETIREMENT FROM 117 MATCHES DUE TO ARM INJURY. [2]

Player	**Current Rank (as of 2-2014)**	**injury**	**date of injury (by week)**
Rafael Nadal	1 Mens	Left shoulder tendinitis	45/2010 - 47/2010
Rafael Nadal	1 Mens	Arm	33/2007 - 35/2007
Rafael Nadal	1 Mens	Shoulder	24/2006 - 25/2006
Rafael Nadal	1 Mens	Shoulder (doubles)	42/2004 - 52/2004
Rafael Nadal	1 Mens	Shoulder	21/2003 - 25/2003
Novak Djokovic	2 Mens	Shoulder	45/2011 - 47/2011
Novak Djokovic	2 Mens	Sore right shoulder	33/2011 - 35/2011
Novak Djokovic	2 Mens	Shoulder	5/2011 - 8/2011
Stanislas Wawrinka	3 Mens	Left Shoulder	5/2006 - 5/2006
David Ferrer	4 Mens	Right shoulder	29/2010 - 33/2010
David Ferrer	4 Mens	Shoulder (doubles)	19/2006 - 19/2006
Juan Martin del Potro	5 Mens	Shoulder	45/2011 - 2/2012
Juan Martin del Potro	5 Mens	Wrist	6/2010 - 2/2011
Juan Martin del Potro	5 Mens	Wrist	2/2010 - 3/2010
Juan Martin del Potro	5 Mens	Wrist	41/2009 - 45/2009
Tomas Berdych	6 Mens	Right shoulder	34/2013 - 35/2013
Tomas Berdych	6 Mens	Left wrist	6/2013 - 8/2013
Tomas Berdych	6 Mens	Right shoulder	17/2012 - 19/2012
Tomas Berdych	6 Mens	Right shoulder	35/2011 - 37/2011
Tomas Berdych	6 Mens	Right shoulder	33/2011 - 35/2011
Andy Murray	7 Mens	Elbow	16/2011 - 18/2011
Andy Murray	7 Mens	Wrist	7/2011 - 15/2011
Andy Murray	7 Mens	Left wirst	40/2009 - 44/2009
Andy Murray	7 Mens	Wrist	20/2007 - 32/2007
Richard Gasquet	9 Mens	Shoulder	5/2011 - 8/2011
Richard Gasquet	9 Mens	Shoulder	12/2009 - 16/2009
Richard Gasquet	9 Mens	Right shoulder	7/2009 - 8/2009
Richard Gasquet	9 Mens	Right elbow	44/2008 - 1/2009
Richard Gasquet	9 Mens	Elbow	21/2006 - 21/2006

[1] See http://tennis.matchstat.com/AllInjuries/
[2] Id.

Richard Gasquet	9 Mens	Wrist	12/2004 - 14/2004
Jo-Wilfried Tsonga	10 Mens	Right arm (doubles)	33/2011 - 35/2011
Jo-Wilfried Tsonga	10 Mens	Right arm	32/2011 - 33/2011
Jo-Wilfried Tsonga	10 Mens	Wrist	44/2009 - 45/2009
Jo-Wilfried Tsonga	10 Mens	Right Arm	26/2005 - 5/2006
Milos Raonic	11 Mens	Right shoulder	41/2010-52/2010
Tommy Haas	12 Mens	Shoulder	32/2013-33/2013
Tommy Haas	12 Mens	Shoulder	41/2009-42/2009
Tommy Haas	12 Mens	Shoulder	17/2008-24/2008
Tommy Haas	12 Mens	Right shoulder	3/2008-8/2008
Tommy Haas	12 Mens	Right shoulder	19/2007-26/2007
Tommy Haas	12 Mens	Wrist	15/2006-21/2006
Tommy Haas	12 Mens	Shoulder	9/2006-9/2006
John Isner	13 Mens	Shoulder (doubles)	29/2011-31/2011
John Isner	13 Mens	Shoulder	31/2010-33/2010
Mikhail Youzhny	15 Mens	Right Elbow	44/2013-2/2014
Mikhail Youzhny	15 Mens	Wrist	3/2010-6/2010
Tommy Robredo	16 Mens	Wrist	41/2013-3/2014
Tommy Robredo	16 Mens	Wrist	10/2009-12/2009
Nicolas Almagro	17 Mens	Wrist	28/2008-35/2008
Nicolas Almagro	17 Mens	Right wrist	19/2008-22/2008
Nicolas Almagro	17 Mens	Right Elbow	37/2007-42/2007
Nicolas Almagro	17 Mens	Right Shoulder	40/2004-45/2004
Jerzy Janowicz	19 Mens	Right Arm	29/2013-32/2013
Kei Nishikori	20 Mens	Arm	2/2009-6/2009
Agnieszka Radwanska	3 Womens	Right shoulder	21/2013 - 25/2013
Agnieszka Radwanska	3 Womens	Right shoulder	34/2012 - 35/2012
Agnieszka Radwanska	3 Womens	Right elbow	9/2012 - 10/2012
Agnieszka Radwanska	3 Womens	Right shoulder (doubles)	32/2011 - 34/2011
Agnieszka Radwanska	3 Womens	Right hand	34/2009 - 35/2009
Agnieszka Radwanska	3 Womens	Right forearm	24/2008 - 25/2008
Agnieszka Radwanska	3 Womens	Right wrist strain	20/2007 - 21/2007
Victoria Azarenka	4 Womens	Right shoulder	20/2012 - 22/2012
Victoria Azarenka	4 Womens	Right hand strain	32/2011 - 35/2011
Victoria Azarenka	4 Womens	Right elbow contusion	19/2011 - 21/2011
Victoria Azarenka	4 Womens	Shoulder	16/2011 - 17/2011
Victoria Azarenka	4 Womens	Right shoulder	31/2010 - 33/2010
Victoria Azarenka	4 Womens	Right shoulder	14/2009 - 17/2009
Victoria Azarenka	4 Womens	Right shoulder	42/2008 - 1/2009
Maria Sharapova	5 Womens	Right shoulder	34/2013 - 1/2014
Maria Sharapova	5 Womens	Right elbow	11/2010 - 19/2010

Maria Sharapova	5 Womens	Right shoulder	31/2008 - 20/2009
Maria Sharapova	5 Womens	Right shoulder	25/2008 - 26/2008
Maria Sharapova	5 Womens	Right shoulder	40/2007 - 45/2007
Maria Sharapova	5 Womens	Shoulder	14/2007 - 21/2007
Angelique Kerber	6 Womens	Left shoulder	29/2010 - 31/2010
Angelique Kerber	6 Womens	Right wrist	19/2008 - 24/2008
Angelique Kerber	6 Womens	Shoulder	10/2008 - 11/2008
Simona Halep	7 Womens	Left shoulder	29/2010 - 31/2010
Simona Halep	7 Womens	Right wrist	19/2008 - 24/2008
Simona Halep	7 Womens	Shoulder	10/2008 - 11/2008
Jelena Jankovic	8 Womens	Wrist	39/2009 - 42/2009
Jelena Jankovic	8 Womens	Right forearm	24/2008 - 26/2008
Petra Kvitova	9 Womens	Elbow	14/2009 - 16/2009
Sara Errani	10 Womens	Right shoulder	30/2011 - 31/2011
Sara Errani	10 Womens	Right shoulder	20/2011 - 21/2011
Sara Errani	10 Womens	Right shoulder	27/2010 - 28/2010
Sara Errani	10 Womens	Right shoulder	42/2009 - 2/2010
Sara Errani	10 Womens	Right arm	38/2009 - 39/2009
Sara Errani	10 Womens	Right shoulder	8/2009 - 14/2009
Sara Errani	10 Womens	Shoulder	29/2008 - 30/2008
Caroline Wozniacki	11 Womens	Right shoulder	1/2014-2/2014
Caroline Wozniacki	11 Womens	Shoulder	27/2011-34/2011
Ana Ivanovic	12 Womens	Left wirst (doubles)	32/2011-33/2011
Ana Ivanovic	12 Womens	Left wrist (doubles)	23/2011-24/2011
Ana Ivanovic	12 Womens	Left wrist	20/2011-23/2011
Ana Ivanovic	12 Womens	Shoulder	6/2010-12/2010
Ana Ivanovic	12 Womens	Right hand	32/2008-35/2008
Dominika Cibulkova	13 Womens	Right elbow	33/2012-34/2012
Dominika Cibulkova	13 Womens	Right shoulder	27/2010-30/2010
Roberta Vinci	14 Womens	Right shoulder	18/2013-20/2013
Roberta Vinci	14 Womens	Right wrist	41/2012-43/2012
Roberta Vinci	14 Womens	Right wrist	21/2012-22/2012
Roberta Vinci	14 Womens	Right elbow (doubles)	17/2011-18/2011
Roberta Vinci	14 Womens	Wrist	27/2009-28/2009
Roberta Vinci	14 Womens	Shoulder	6/2008-15/2008
Carla Suarez Navarro	15 Womens	Right elbow	37/2011-38/2011
Carla Suarez Navarro	15 Womens	Right elbow	8/2011-23/2011
Carla Suarez Navarro	15 Womens	Right elbow	7/2009-8/2009
Sabine Lisicki	16 Womens	Right wrist	30/2013-34/2013
Sabine Lisicki	16 Womens	Rught shoulder	31/2009-35/2009

Sabine Lisicki	16 Womens	Right shoulder	28/2009-30/2009
Sabine Lisicki	16 Womens	Shoulder	18/2009-25/2009
Samantha Stosur	17 Womens	Right arm	31/2010-34/2010
Sloane Stephens	18 Womens	Left wrist	38/2011-2/2012
Kirsten Flipkens	20 Womens	Right wrist	28/2010-38/2010

95 TOP ATP PROFESSIONALS ARE CURRENTLY SIDELINED BECAUSE OF ARM INJURY. [3]

Of the top 100 ATP professionals, in just the past 6 months, there were 28 matches retired due to arm, wrist, elbow, and shoulder pain. This does not account for all of the matches where they just played through the pain or those who didn't play at all. Amongst these pros Head racquets were played with the most (10) with Babolat coming in at a close second (8). Head racquets also had the most shoulder injuries at 6. Below is the complete listing.[4]

[3] see http://www.tennisinsight.com/injuries.php
[4] http://www.tennisinsight.com/injuries.php

Player	Type of injury	Date of injury	Model of racquet	Manufacturer
Donald Young	Left shoulder	Feb 24 2014	Head YOUTEK Radical Midplus	Head
Lleyton Hewitt	Shoulder	Feb 17 2014	YONEX VCORE 95	Yonex
Filippo Volandri	Shoulder	Feb 17 2014	Head YOUTEK IG Prestige Midplus	Head
Benjamin Becker	Shoulder	Feb 17 2014	Babolat Pure Control	Babolat
Roberto Bautista Agut	Right wrist	Feb 3 2014	Wilson Six.One 95 BLX (16x18)	Wilson
Aleksandr Nedovyesov	Right shoulder	Feb 3 2014	Babolat pure drive	Babolat
Bradley Klahn	Wrist	Jan 27 2014	Head YOUTEK IG Speed	Head
Jack Sock	Arm	Jan 20 2014	Babolat AeroPro Drive	Babolat
Bradley Klahn	Wrist	Jan 20 2014	Head YOUTEK IG Speed	Head
Tommy Haas	Shoulder	Jan 13 2014	Head YouTek IG Prestige Midplus	Head
Nicolas Almagro	Shoulder	Jan 13 2014	Dunlop Biomimetic Tour 500 Pro	Dunlop
Tommy Robredo	Right arm	Dec 28 2013	Dunlop Biomimetic M6.0	Dunlop
Mikhail Youzhny	Right elbow	Oct 28 2013	Head YouTek IG Extreme Pro	Head
Pablo Andujar	Right elbow	Oct 28 2013	Prince EXO3 Tour 100	Prince
Mikhail Kukushkin	Right elbow	Oct 28 2013	Head YOUTEK Graphene Speed MP	Head
Aleksandr Nedovyesov	Right elbow	Oct 28 2013	Babolat pure drive	Babolat
Gael Monfils	Left wrist	Oct 28 2013	Wilson Blade 98 (18x20)	Wilson
Tommy Robredo	Wrist	Oct 6 2013	Dunlop Biomimetic M6.0	Dunlop
Nikolay Davydenko	Right wrist	Sep 30 2013	Babolat AeroPro Drive	Babolat
Nikolay Davydenko	Wrist	Sep 23 2013	Babolat AeroPro Drive	Babolat
Janko Tipsarevic	Right wrist	Sep 16 2013	Tecnifibre TFight 325 TP ATP	Tecnifibre
Michal Przysiezny	Right shoulder	Sep 2 2013	Wilson Blade 98 (18x20)	Wilson
Tomas Berdych	Right shoulder	Aug 18 2013	Head YouTek IG Instinct	Head
Tommy Haas	Shoulder	Aug 5 2013	Head YouTek IG Prestige Midplus	Head
Vasek Pospisil	Shoulder	Aug 5 2013	Wilson Six.One 95 BLX (16x18)	Wilson
Benoit Paire	Elbow	Jul 15 2013	Babolat AeroPro Drive	Babolat
Jerzy Janowicz	Right arm	Jul 15 2013	Babolat Pure Control Tour	Babolat
Mikhail Kukushkin	Right shoulder	Jul 8 2013	Head YOUTEK Graphene Speed MP	Head

Caroline Wozniacki headlines a growing list of already-injured players in 2014 [Updated]

ATP, Injuries, WTA | Comments

Caroline Wozniacki tweaked her shoulder before leaving for Australia. (Atsushi Tomura/Getty Images)

The 2014 tennis season has barely begun, yet the list of the injured and ailing has grown with each passing day. The most high-profile injury concern belongs to the newly-engaged Caroline Wozniacki, who was forced to withdraw from the Brisbane International with a right shoulder injury. Wozniacki felt the pain after her last practice before flying to Australia to start the season, but she ‘s still optimistic she will be able to play next week’s Sydney International.

TENNIS ICONS SUFFER TEMPORARY OR PERMANENT RETIREMENT FROM TENNIS AND THIS IS DEVASTATING FOR THE SPORT OF TENNIS.

RECENTLY CLISTERS and RODDICK RETIRED FROM SHOULDER INJURY. JUSTINE HENIN FROM ELBOW INJURY. SHARAPOVA, MURRAY and JUAN DEL POTRO SUFFERED TEMPORARY RETIREMENT

Half of all debilitating professional injuries are arm injuries. At any given time over 30% of top players are sidelined from arm injury. 80% of professional men and women have suffered arm injury or surgery. The industry cannot continue to avoid the issue.

ANDY RODDICK RETIRES FROM SHOULDER INJURY AFTER SURGERY- Roddick had suffered a knee injury in 2009, which set him back in training, and endured a serious shoulder surgery following his Wimbledon loss in 2010. Later that year, he announced that he had mononucleosis, a viral infection that includes symptoms similar to that of the flu. Around the same time, he experienced a groin and separate shoulder injury. In August 2012, 30-year-old Roddick announced plans to retire from tennis.

Henin Says She Is Retiring for Good With Elbow Injury

By CHRISTOPHER CLAREY

Published: January 26, 2011
http://www.nytimes.com/2011/01/27/sports/tennis/27henin.html?_r=0

Azarenka withdraws from Rome with shoulder injury

By Simon Cambers

Wed May 16, 2012 6:58pm EDT

(Reuters) - World number one Victoria Azarenka suffered a blow to her French Open preparations when she was forced to pull out of the Italian Open with a right shoulder injury.

Del Potro Sidelined by Surgery on Wrist

By CHRISTOPHER CLAREY

Published: May 4, 2010

Injury forces Agnieszka Radwanska out of New Haven
By Jim Fuller special to EmiratesUSOpenSeries.com

NEW HAVEN - For more than a set on Tuesday evening Agnieszka Radwanska's shoulder was speaking just one word to her: No.


Sharapova, Citing Shoulder Injury, Will Miss Open

Ronald Martinez/Getty Images

Maria Sharapova has played only one match on tour since her second-round loss at Wimbledon in June.

By BEN ROTHENBERG

Published: August 21, 2013


Nadal to take time out to rest recurring shoulder injury after Australian Open

By Sportsmail Reporter

UPDATED: 17:45 EST, 29 December 2011



Tennis - Steve Darcis undergoes shoulder surgery and to miss at least four months

Tennis - Darcis shocked Rafael Nadal in Wimbledon first round

Tennis Stories 11 Oct 2013 - 11:28 / by **Prakash** / reads 668.
Source:



Victoria Azarenka out in Rome

Updated: May 17, 2012, 5:55 PM ET

Associated Press

ROME -- Top-ranked Victoria Azarenka has withdrawn from the Italian Open because of a right shoulder injury.

David Ferrer was then supposed to play in the 2010 International German Open as the second seed, but had to withdraw due to a shoulder injury.

Unfortunately my old shoulder injury flared up before the match and I had to retire from the tournament. My Life, Li Na

Sam Querrey Pulls Out of 2011 U.S. Open To Recover from Elbow Injury

By [Diana Sir Louis](), Contributor *Aug 20, 2011*

Wimbledon 2011: Elbow injury strikes cruel blow for Heather Watson

Wednesday 22 June 2011 13.46 EDT

Heather Watson feels the pain from the elbow injury which reduced the effectiveness of her serve. Photograph: Julian Finney/Getty Images

Andy Murray: “I had shoulder and elbow surgery while I was playing and I can remember what a frustrating time it was."

Novak Djokovic pulls out of Paris Masters with shoulder injury

Novak Djokovic has pulled out of the Paris Masters ahead of his scheduled quarter-final against Jo-Wilfried Tsonga, citing inflammation in his right shoulder.

Feeling the strain: Novak Djokovic has pulled out of the Paris Masters with a shoulder injury Photo: REUTERS

By Simon Briggs

10:59AM GMT 11 Nov 2011

Injured Berdych to miss Davis Cup

Associated Press

Updated Mar 29, 2013 1:15 PM ET

PRAGUE (AP)
Tomas Berdych has a shoulder injury and will miss the defending champion Czech Republic's Davis Cup quarterfinal against Kazakhstan next month.

Ice on Shoulder

Arm-related injuries to marquee players in 2012 included Vera Zvonareva (shoulder), Aleksandra Wozniak (shoulder), Alberta Brianti (shoulder), FlaviaPennetta (wrist), and JelenaDokic (wrist),

Barthel retires from Bad Gastein with shoulder injury

Wednesday, July 17, 2013 /by AP

AP Photo

BAD GASTEIN, Austria (AP)—Top-seeded Mona Barthel of Germany pulled out with a shoulder injury while trailing 6-2, 4-3 to the 725th-ranked Lisa-Maria Moser in the second round of the Gastein Ladies on Wednesday.

Playing in her first WTA event, Moser broke twice to take the opening set and the Austrian wildcard was a break up in the second when the 31st-ranked Barthel withdrew.

Barthel, who was looking to reach her fourth quarterfinal of the season and first since winning in Paris in February, took over the top seeding after defending champion **Alize Cornet of France pulled out with a shoulder injury.**

Haas retires with bad shoulder in Brazil semis

Jelena Dokic thought career was over after wrist surgery in 2012

Tennis Guru November 1, 2013 Tennis Feature, Tennis News, WTA No comments

Italy's Flavia Pennetta retires due to wrist injury

Flavia Pennetta**: Retired four games into her match against Eugenie Bouchard at Hopman Cup with a right wrist injury. That’s the same wrist that required surgery and kept her out of most of the 2012 season.**

Date

January 2, 2014

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Brad Elborough

Read more: http://www.smh.com.au/sport/tennis/italys-flavia-pennetta-retires-due-to-wrist-injury-20140102-30862.html#ixzz2ulK6spoC

World No.10 Jo-Wilfried Tsonga suffering a wrist injury

- By Leo Schlink
- *Herald Sun*
- December 31, 2009 10:24AM

World No.10 Jo-Wilfried Tsonga is struggling to be fit for the Australian summer circuit after injuring his wrist.

Sabine Lisicki Withdraws From Pattaya Open Citing a Shoulder Injury

Canadian tennis player Aleksandra Wozniak out with shoulder injury

Canadian tennis player Aleksandra Wozniak will be out of action for three months due to a right shoulder injury.

Injury beats Melzer

PARIS: Austria's world No.27 Jurgen Melzer on Saturday withdrew from the Australian Open with a shoulder injury.

Read more: http://www.smh.com.au/sport/tennis/tsonga-in-form-20140105-30c1m.html#ixzz2ullFURbe

Brian Baker's comeback story gets better and better

Updated 6/28/2012 11:55 AM

WIMBLEDON, England (AP) – There were plenty of low points along the way back to tennis' biggest stages for Brian Baker. None worse, perhaps, than waiting to have reconstructive surgery on his right elbow in February 2008.

Vera Zvonareva has shoulder surgery

WTA | Comments

Lleyton Hewitt retires against Marinko Matosevic in second round at Delray Beach Open

Posted Thu 20 Feb 2014, 2:57pm AEDT

Australia's number one Lleyton Hewitt was forced to retire after one set of his second-round clash with countryman Marinko Matosevic at the Delray Beach Open on Thursday (AEDT).

The eighth-seeded Hewitt, who won the inaugural tournament in 1999, dropped the first set 7-6 (7/2) against world number 55 Matosevic before pulling out with a shoulder injury prior to the first game of the second.

ANGELIK KERBER 

CONSUMER SAFETY AND INJURY

According to Keith Story of the Tennis Industry Association of America, 1.8 million recreational tennis players in the United States quit playing tennis altogether in 2011 due to an arm injury. [5]. The Sports Marketing Surveys USA for the Tennis Industry Association reported 10% were from shoulder injury, 7% elbow injury and 5% “arm” injury.

The same TIA study reported in addition to those who quit tennis permanents, of those who stayed in the game, 30% also suffered injury.[6] See Exhibit B attached.

According to International Tennis Federation (ITF), the governing body of the sport, half of all players will suffer elbow injury.[7]

Since the advent of composite racquets 30 years ago, over 150 million players have suffered a wrist, elbow or shoulder injury, according to Mark Kovacs, executive director of the International Tennis Performance Association (ITPA), a global sports science organization that focuses on the game of tennis. Kovacs says the 150 million figure was reported at the International Tennis Federation World Conference in Cairo in November, 2011.

This epidemic did not exist in these vast numbers prior to the advent of hollow, empty or air injected carbon rackets.[8]

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[5] Keith Storey, Sports Marketing Surveys USA for the Tennis Industry Association (10% from shoulder injury, 7% elbow injury and 5% “arm” injury)

[6] T I A S T A T E O F T H E I N D U S T R Y K e y T e n n i s I n d u s t r y I n d i c a t o r s 2 0 11 page 6 (30% of frequent players reported playing less tennis because of health or injury)

[7] http://www.itftennis.com/scienceandmedicine/injury-clinic/tennis-injuries/tennis-elbow. The ITF’s website states:

> “Tennis elbow is the best-known and also the most painful elbow injury in tennis players. An estimated 50% of all tennis players will suffer from tennis elbow in the course of their career. Players aged over 35 are particularly at risk. . .The pain may radiate into the arm, wrist and fingers. The injury usually develops gradually, as a result of multiple micro ruptures and scar tissue at the muscle attachment. ..
> Tennis elbow is a common complaint, but as yet, there is no consensus on the optimal treatment strategy.”

Tennis elbow is an injury. “Injury is the damage sustained by tissues of the body in response to physical trauma.” W, Zernicke R. Biomechanics of musculoskeletal injury. page 2 Champaign, IL: Human Kinetics, 1998

Tennis elbow (or “Lateral epicondylitis”is caused by either abrupt or subtle injury of the muscle and tendon area around the **o**utside of the elbow that damages the tissues. Beasley VidalLS, et al. (2007). Shoulder injuries. In PJ McMahon, ed., Current Diagnosis and Treatment in Sports Medicine, pp. 118-145. New York: McGraw-Hill.

[8] All composite rackets have been made using air injected rackets. 8. Knudson D. Biomechanical research into tennis elbow. Proceedings of ISEA. ISEA 2004.

One upper-limb chronic injury afflicting tennis players is osteoarthritis. Osteoarthritis is the progressive loss of articular cartilage, which begins with fraying, or fibrillation, of the articular surface and progresses to exposure of the subchondral bone. Radiographic images were obtained of both shoulders and the results showed that 33% of tennis players had osteoarthritic changes in their dominant shoulder. [9] Degeneration of the dominant shoulder acromioclavicular joint was 55.5% in the studied group.[10]

A 1989 study shows that 50% of injuries are reoccurrences.[11]

The reported incidence of wrist injuries is higher among females (15.7% of all tennis injuries) than male players (11.2%).[12]

A 1989 Danish study shows that of all injuries 45% were upper limb injuries, 17% shoulder."[13]

In 2003, out of 100,000 tennis players there were 21,300 injuries that required a doctor's visit and 1,228 injuries that were serious enough to require hospitalization or surgery.[14]

According to Monash University 69% of adult tennis injury cases and 40% of child injury cases occurred during formal competition.Forty-five percent of all child tennis injuries in formal play were to the upper extremities. The public exposure of professional tennis and the vast amount of money involved has impacted upon young tennis players, leading to great pressure to practice, high expectations of performance and increasing demands on the human body (Mothadi and Poole 1996). More females (57%) than males (43%) play tennis.Over one-third (37%) of players are over the age of 45 years. Over one-half of all participants (55%) indicated that they participate in tennis once a week.In adult tennis players the upper limbs accounted for 24% of all injuries.Upper limb injuries were more common than lower limb injuries among children.[15]

Wrist injuries have become an increasing common problem since the modern game involves a higher combination of powerful serves and topspin forehands that now account for 75% of all strokes, according to *Sports Medicine & Rehabilitation* (2009).

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[9]British Journal of Sports Medicine 2006; 40:447-450
[10]Am J Sports Med, 1997; 25:809-812
[11]Archives of Internal Medicine, vol. 149(11), pp. 2561-2564, 1989
[12]http://www.sportsinjurybulletin.com/archve/tennis-wrist-injuries
[13]Winge S, Jorgensen U, Lassen Nielsen A, 'Epidemiology of injuries in Danish championship tennis' Int J. Sports Med 1989 Oct; 10(5): 368-71
[14]http://www.democraticunderground.com/discuss/duboard.php?az=view_all&address=364x401653
[15]Monash University Accident Research Centre – Report #144 - 1999

Research conducted found that 70% of children in intensive tennis training programs suffered arm injury, permanent injury or arm surgery before the age of 16. Thousands of these young victims were especially vulnerable because of their underdeveloped tendons and muscles. The medical examinations from doctors concluded that the cause of the injury was the racket. see Adam Johnson medical diagnosis CPSC report.

Many children training under 10 serve underhand due to inability to lift the arm above the shoulder from permanent shoulder damage.

The Epidemic is reaching younger and younger children. The Childrens Hospital of Philadelphia, in Pennsylvania performs hundreds of surgeries on tennis kids every year.

A player survey at an WTA Tournament in the Bronx uncovered that 50% of players had undergone surgery before the age of 16.

Children as young as 8-years-old are hitting balls four to five hours a day, and modern composite racquets have “added too much power and put enormous wear and tear on young bodies,” wrote tennis legend Martina Navratilova in an article entitled, “Sidelined in their Prime” that appeared in the Jan. 9, 2009 edition of *Newsweek.* “More injuries are likely,” she warned, “unless tennis's governing bodies modify the [large numbers of tournaments on the] calendar and fight back against the racquet manufacturers that have hijacked the game.”

Twenty percent of junior players suffer from repetitive stress, compared to just 7.5 percent of professional players,. [16]

BETHANIE MATTEK SANDS 2012 AUSTRALIAN OPEN MIXED DOUBLES CAHMPION

“The racquets do contribute obviously to injuries. Because with the hollow racquets you’ll end up feeling more of the vibration up your arm. Kids have gotten younger and younger with more severe injuries- 10, 11, 12 year old kids potentially getting surgeries. To me it’s just crazy To see kids doing rehab as much as they are taping their shoulders, and the elbow bands. Hopefully that sparks some attention that there needs to be a change”.

[16] see British Journal of Sports Medicine.40(5), 454-459, 2006. See also Patricia Kolowich, MD, on the website, StopSportsInjuries.org

Current Equipment is Illegal under the CPSC rules

Enclosed is the CONSUMER SAFETY PRODUCT COMMISSION PRODUCT RECALL HANDBOOK

CPSC Product Recall Handbook Defines Class B and C Hazard as

Class B Hazard

Exists ... when...moderate injury ... is very likely.

Class C Hazard

Exists ...when moderate injury.. is not necessarily likely, but is possible.

Regardless of whether a product defect is classified as a Class A, B, or C priority hazard, the common element is that each of these defects creates a substantial product hazard that requires corrective action to reduce that risk of injury.

The priority given to a specific product defect provides a guideline for determining how best to communicate with owners and users of the defective product and to get them to respond appropriately. While some companies have exemplary track records in communicating with consumers independently, it is still to a company's advantage to work with the Commission staff, using both the company's and the Commission's skills and resources to conduct an effective product recall.

Regardless of which defect or combination of defect and mechanics aggravating the underlying cause of the injuries, if the result is a HAZARD under the rules, corrective action must be taken.

The CPSC as already begun investigations into the high rate of tennis arm injuries and could even ban the format of the sport as it exists today. All other industries involving products intended to be children are already regulated by the Consumer Safety product commission including Helmets, bats, Skis, snowboards, skateboards, etc. It is only a matter of time when tennis rackets will also require safety standards.

All current empty, hollow, or air injected rackets shock longer than .2 sec at impact and are illegal under CPSC rule 1115 and hazardous to the consumer population, should subject to CPSC regulation, consumer warning labels, standards and recall due to the high likelihood (well over 50%) of procuring injury. See 16 C.F.R. § 1115.

4. Failure to use known technology to prevent injury is negligent and subject to punitive damages. Under product liability law, once technology exist to prevent injury, if it is not used, it can subject parties to punitive damages. ***See Prosser, Handbook on the law of Torts. sec 7.04 8.04*** **(Failure to use known safety features is a basis for product liability).**

Early cases involving seat belts found the automobile companies liable for not using known safety technology whenever there is a "foreseeable risk of harm". This DUTY OF CARE TO THE CONSUMER is elevated when the foreseeable end users are minors under the age of 16. As the game of tennis demands more rigorous physical endurance the number of children and juniors in training camps around the world have grown to numbers in the millions all vunerable if safety technology is not mandatory, required and strictly enforced.

"An injured test consumer can recover on the theory that the product would have been safe had the manufacturer incorporated safety features that were known at the time of product was designed." see *Product Liability* - Legal Dictionary

This is not a cause based theory of liability but rather a prevention based duty of reasonable care to the consumer.

RACKET SHOCK IS THE CAUSE

The paramount authority Dr Stuart Miller, the ITF's Head of Science & Technical Commission, after years of studying all possible causes of the injuries concluded in a 2006 issue of *British Journal of Sports Medicine* that racket shock is the cause of injuries:

> "By allowing the racket to be swung faster, the decrease in mass generates greater shock to the hand for impacts that are not at the centre of percussion. On the basis of a review of biomechanical evidence, it has been concluded that shock is the most likely cause of tennis elbow. [17]

> "The combination of the increased stiffness of modern rackets and the tendency for tennis balls to have become harder has led to an increased shock transmission from the racket to the player.[18]

> "Although modern racket technology has produced many positive effects, it is arguable that injury rates have increased as a result. . .Anecdotal evidence suggests that the vast majority of upper limb injuries are chronic; having been developed over time through repetition….it is not unreasonable to suggest that the trend for increased power is responsible for the increased number of injuries seen in today's game. "[19]

> "The ball leaves the strings before even the stiffest racquets can recoil, so most all the energy in the shock wave stresses the racquet and arm and does not return to the ball,"[20]. "After the ball has left the strings the player's arm is beginning to experience not only the forces of the shock wave, but also forces of racquet vibrations. "[21]

The fact that racket shock is the culprit is well supported.

The racket is a primary cause for the elbow to endure "the perfect storm".[22]

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[17] Miller, **Modern tennis rackets, balls, and surfaces** Br J Sports Med. 403 (May 2006)
[18] Id at 401
[19] Id.
[20] Dr Duane Knudson, Associate Professor, Department of Physical Education & Exercise Science, California State University
[21] Id. Henning, Influence of racket properties, Id

[22] David Bayliff Physical Therapist, MPT.

This epidemic did not exist in these vast numbers prior to the advent of light air injected rackets.[23]

In Influence of Racket Properties on Injuries and Performance in Tennis , Dr. Henning concludes that the characteristics of the racket causes racket shock.[24]

> "Racket properties may affect tennis elbow development. Shock and vibration to the arm is influenced by the location of ball impacts on the racket head, racket stiffness, and grip force. Beginners experience increased arm loads, and they hit the ball lower on the racket head. Tennis rackets behave differently during actual play compared with the performance predicted by physics"

Stated RacquetResearch.com: "Poor stroking technique is frequently accused, conveniently diverting scrutiny from racquet design, but, as the calculations on this site prove, risk factors for tennis elbow include: (1) light racquet weight and (2) head-heavy balance. Stiff frames are also bad. What is good for minimizing elbow damage is low Shock, low Elbow Crunch, low Torque, and low Moment.

Shock in biomechanical load will cause stress and injury to muscle, tissues and tendons[25].

REMEDIES

MINIMUM SAFETY CHARACTERISTICS OF RACKETS

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[23] Miller, All composite rackets have been made using air injection.. 8. Knudson D. Biomechanical research into tennis elbow. Proceedings of ISEA. ISEA 2004.

[24] Exercise & Sport Science Review. 2007 Apr;35(2):62-6.
15 Miller, All composite rackets have been made using air injected rackets. Knudson D. Biomechanical research into tennis elbow. Proceedings of ISEA. ISEA 2004.

Numerous studies have shown that the characteristics of the racket affect the shock load up to 5 times depending on the construction of the rackets.[26]

Old wooden rackets vibrate at about 90 Hz,3 whereas modern rackets can be made to vibrate at frequencies up to 200 Hz."[27] In the old wood rackets, vibration disappeared quickly because it was dampened by the flex of the solid wood, but the new stiffer, lighter and hollow conventional frames do a poor job of snuffing out the vibrations, so they transfer this shaking to the arm that can stealthily sabotage the elbow, wrist, forearm and shoulder. [28]

In Transfer of tennis racket vibrations onto the human forearm., Hennig reported that "Between different racket constructions, almost threefold differences in acceleration values could be observed." [29]

The most recent study conducted by the Othrokinetic Labs showed that modern air injected or hollow rackets have shock duration up to 5 times that of a solid-core racket.

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[26] ***Influence of Racket Properties on Injuries and Performance in Tennis*****, Henning concludes that it is the characteristics of the racket which causes racket shock.**

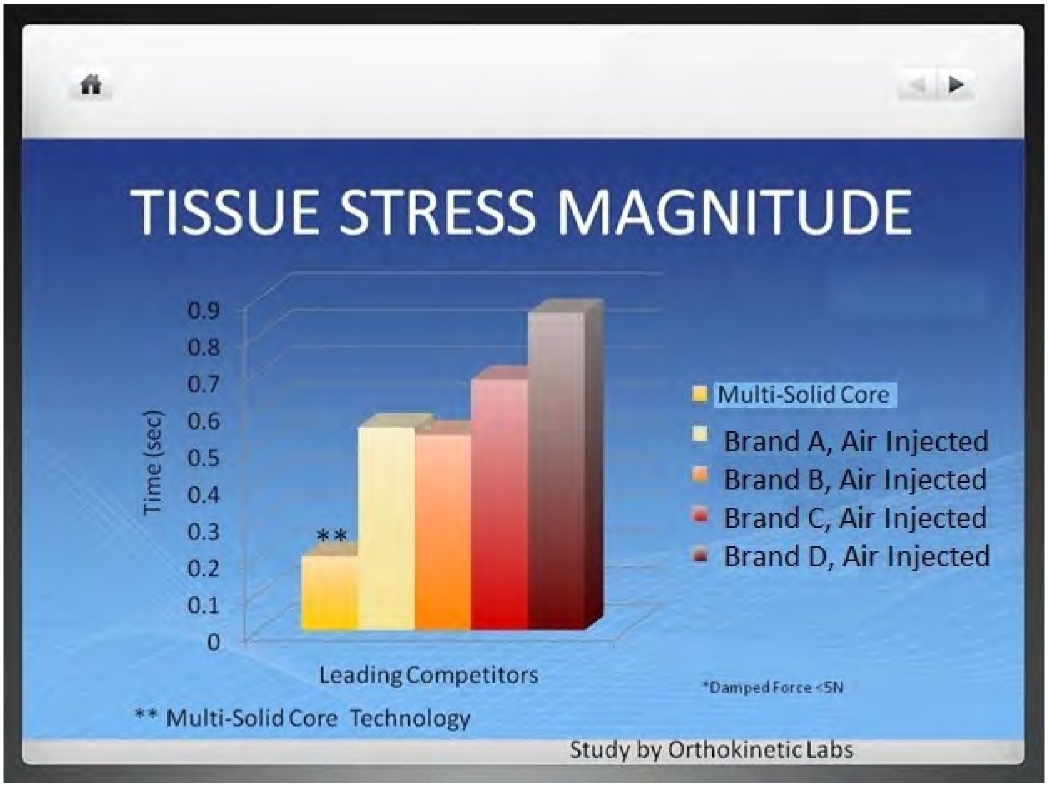
abstract	abstract	20	20		
			1	false	

[27] . 8. Knudson D. Biomechanical research into tennis elbow. Proceedings of ISEA. ISEA 2004.

[28] Orthokinetic labs

[29] . " One of several factors suspected in the development of lateral epicondylitis, often referred to as tennis elbow, is the impact-induced vibration of the racket-and-arm system at ball contact."

RACKET SHOCK STUDY



The study was conducted by an independent third party test facility located in Shallotte, North Carolina that specializes in medical device and sport equipment testing. OrthoKinetic Technologies, LLC, the parent company, is a leading regulatory and consulting firm specializing in regulatory and test strategies for medical devices and sport equipment.

A solid core racket dampened vibrations four times quicker with less vibratory forces than other models tested upon impact with a standardized force.

Both professional and recreational players get repetitive force transmission and vibrations to the tissues of the arm with the hits of the ball, and some of the shock is transmitted to the arm. The more prolonged the shock and vibration, the greater the risk for tissue injury.[30]

In the study, the solid core rackets vibrated for less than 1/5 of a second on ball contact, compared to an average of 7/10 of a second for other models tested. That means a player hitting

[30] Orthokinetics

180 balls in a typical tennis match is subjected to more than 111 seconds of shock & vibration dwell time with the other brands versus a mere 32 seconds with the multi-solid core rackets. Having a shock needle in the tendon for 2 minutes can cause severe harm especially to children and minors whose tendons are not even fully developed.

The extent of frame vibration transmitted to the arm holding the racquet depends largely on how well it is dampened. Multi solid-core XeneCore construction and manufacturing process acts as a super dampener to eliminate most all of the damaging vibrations.

In, "Prediction of Impact Shock Vibrations at Tennis Player's Wrist Joint: Comparison between Conventional Weight Racket and Light Weight Racket with Super Large Head Size" in the Journal of System Design and Dynamics, the authors concluded:

> "The result showed that the shock vibration of the super-light weight balanced racket with super-large sized head is much larger than that of the conventional weight balanced type racket. The result showed that the shock vibration of the super-light weight balanced racket with super-large sized head is much larger than that of the conventional weight balanced type racket." [31]

31

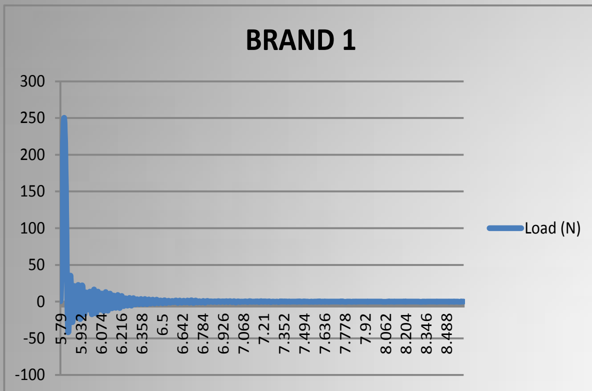
Kawazoe, Yoshihiko; Et al, Prediction of Impact Shock Vibrations at Tennis Player's Wrist Joint: Comparison between Conventional Weight Racket and Light Weight Racket with Super Large Head Size, Journal of System Design and Dynamics Vol. 4 (2010) No. 2 P 331-347

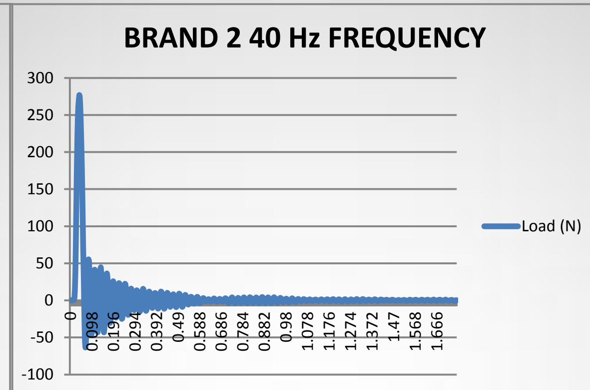
RACQUET SHOCK STUDY

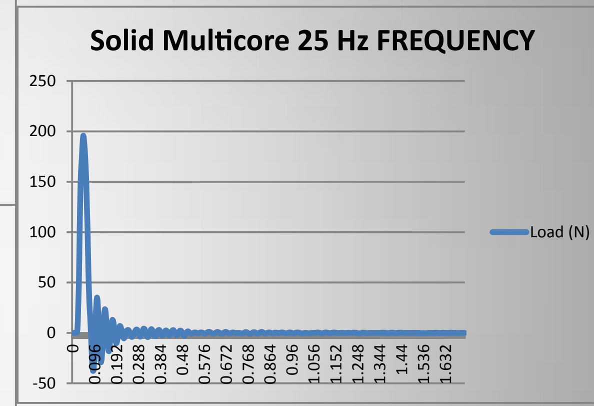
MULTI CORE RACQUETS VS. AIR MOLDED RACQUETS

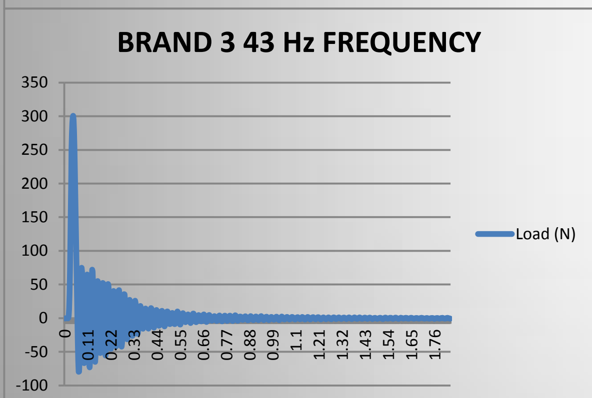
AIR MOLDED RACQUETS TRANSMIT OVER 43,000 lbs OF FORCE PER MATCH ON THE ARM. SOLID MULTICORE RACQUETS TRANSMIT LESS THAN 14,000 lbs OF FORCE.

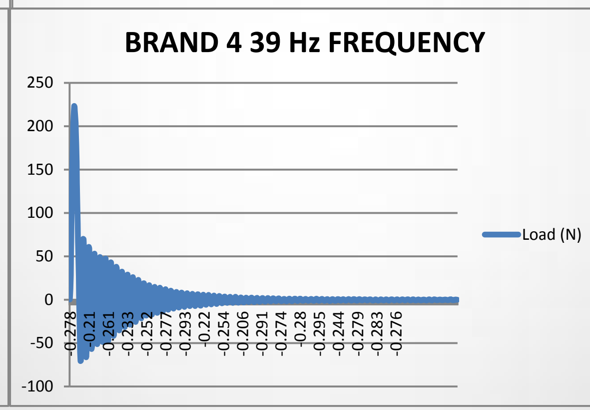
SHOCK AMPLITUDE





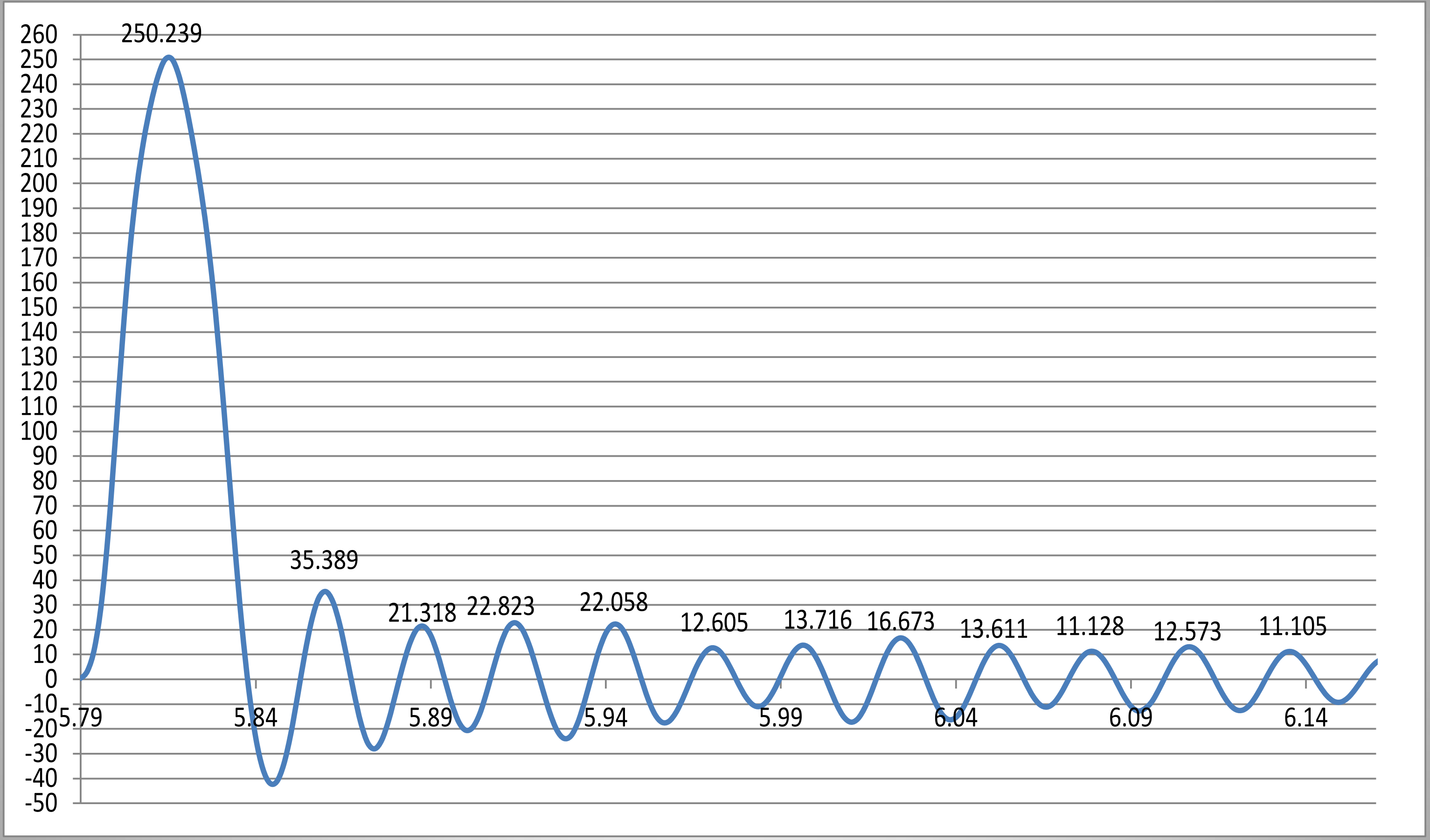






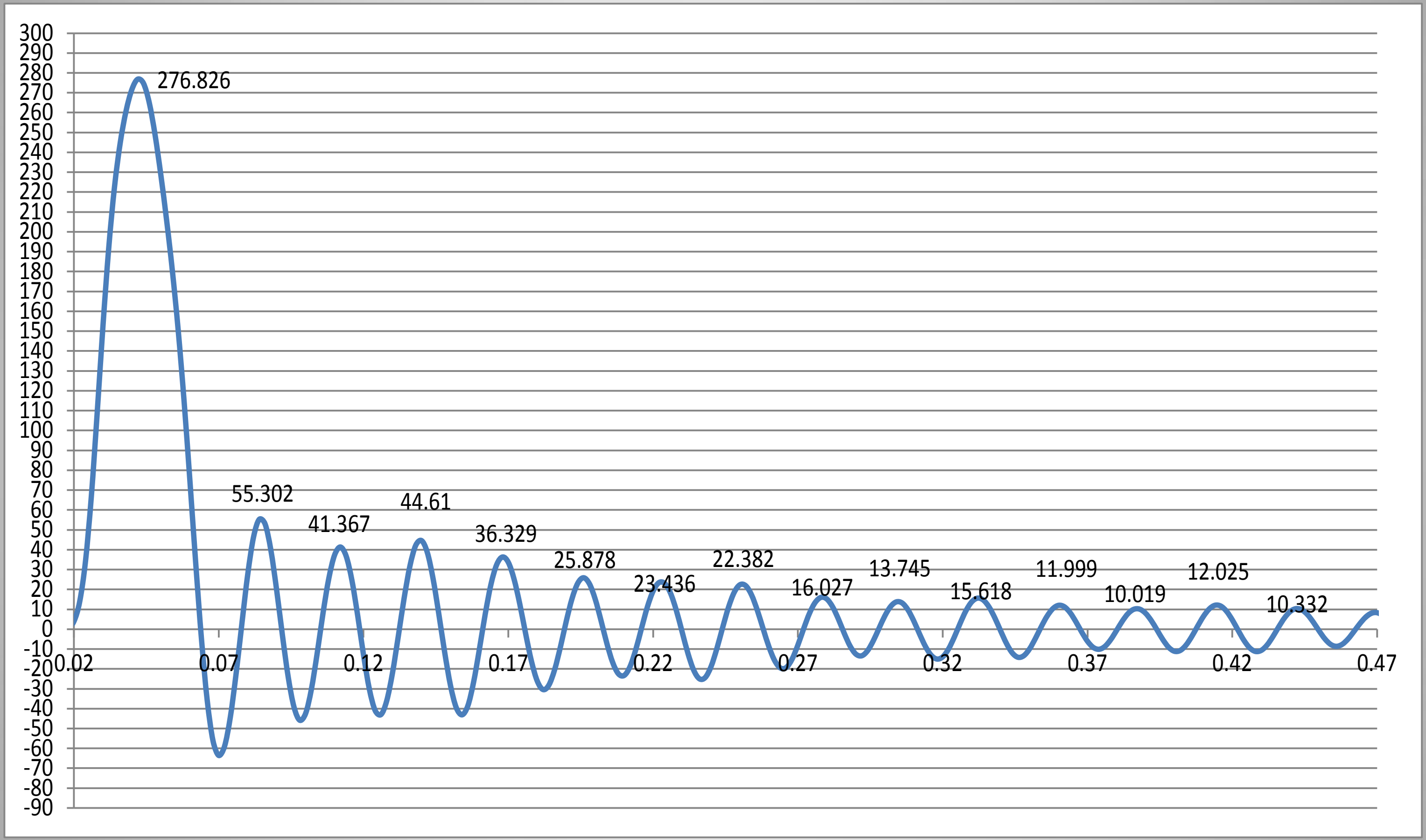
Multi solid core racquets showed lower frequencies (25Hz) or cycles per second of vibration cycles compared to 40Hz average with the air molded racquets. This is significant as the number of oscillations corresponds to the amount of energy transmitted to the arm. If you add the amplitude of all the oscillations you will get the amount of energy transmitted to the arm in a single hit of the ball. We call this shock amplitude. In a typical match you hit the ball 180 times. If you multiply the shock amplitude by how many times you hit the ball you will find out how much energy your arm is absorbing.

BRAND 1



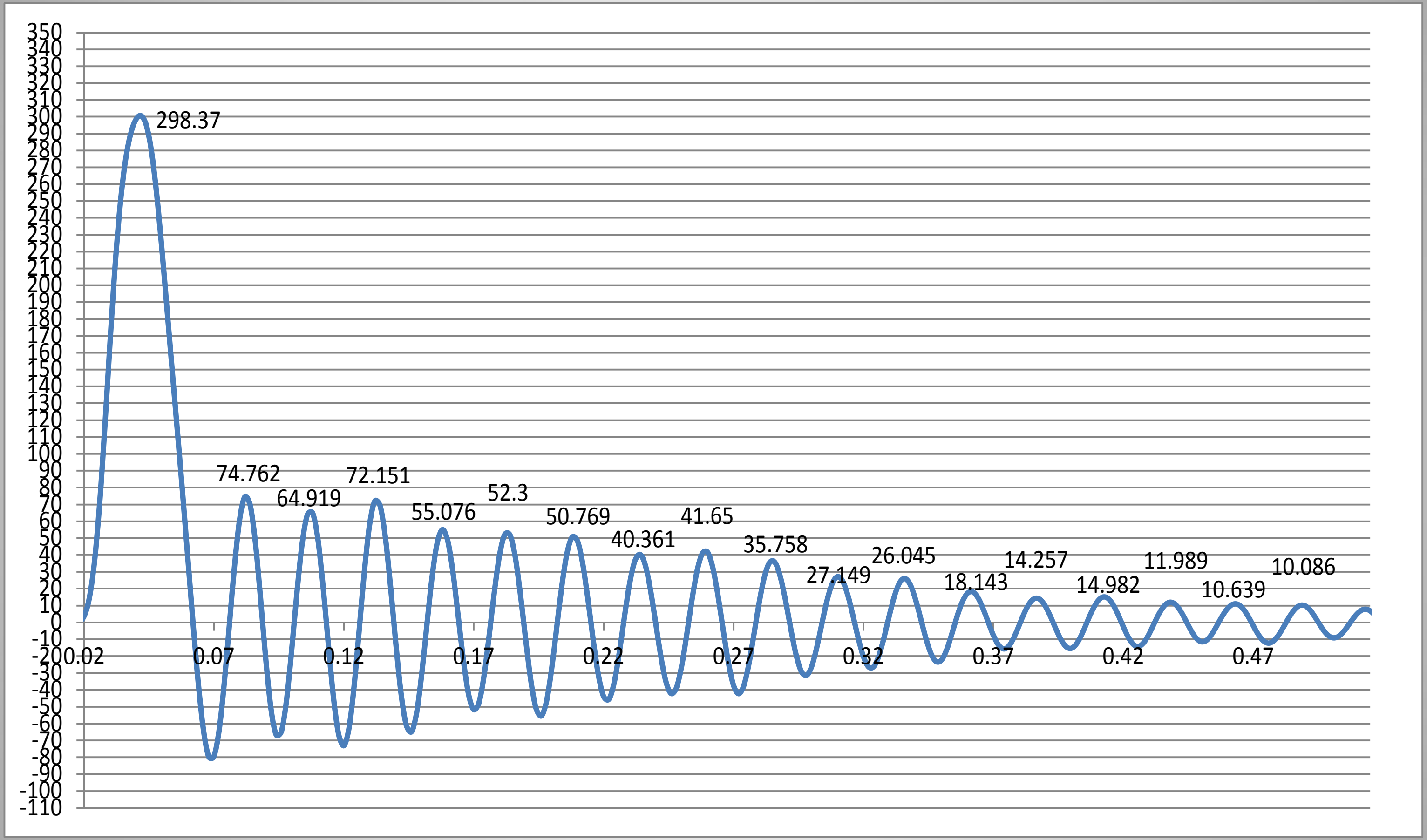
12 cycles over 0.344 seconds with a total of 604.2 newtons (135.829 pound-force) per ball hit. During a typical match this brand expells 108,756 newtons (24,449.321 pound-force) to your arm.

BRAND 2



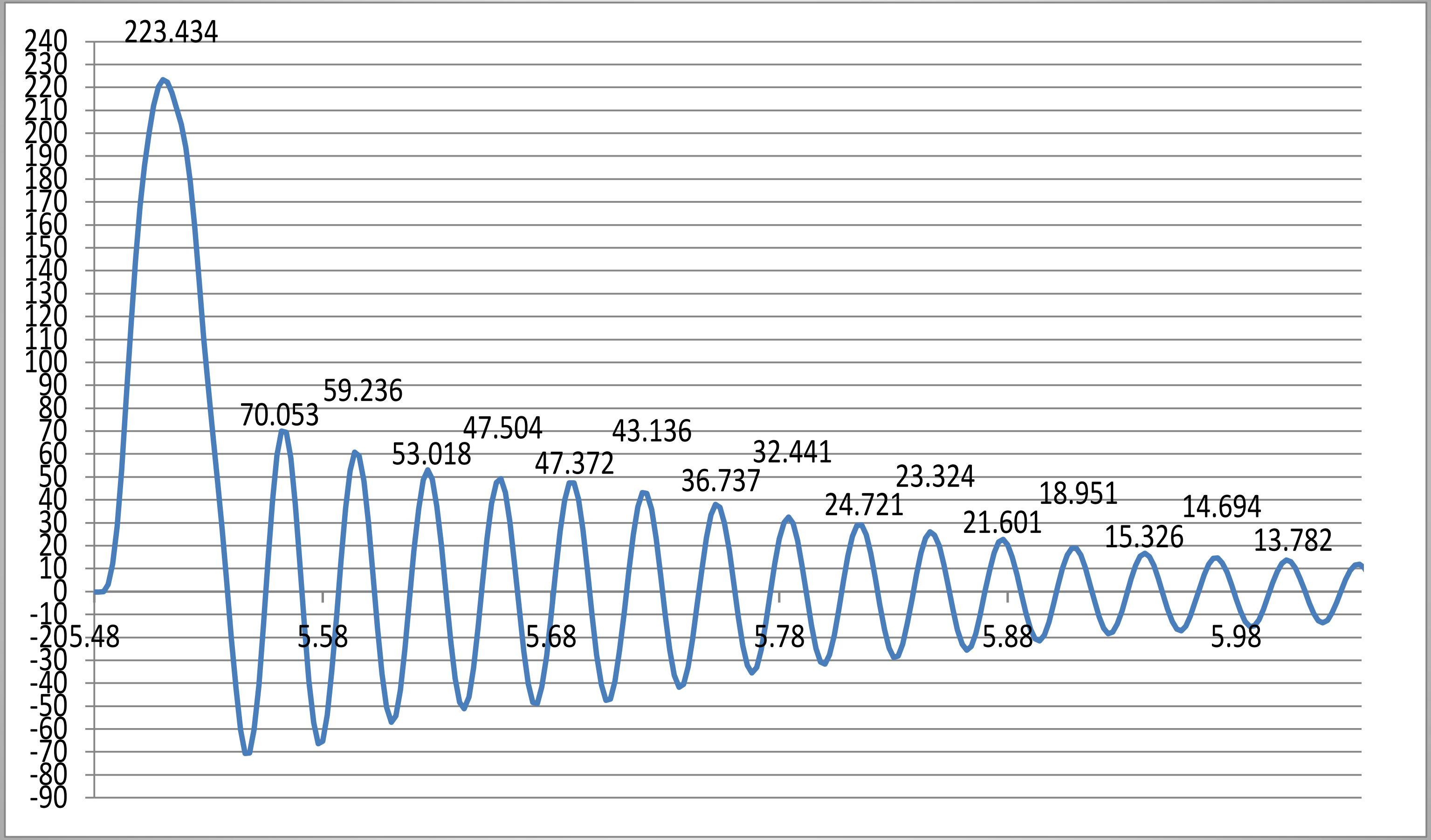
15 cycles over 0.506 seconds with a total of 954.963 newtons (214.684 pound-force) per ball hit. During a typical match this brand expells 171,893.34 newtons (38,643.160 pound-force) to your arm.

BRAND 3



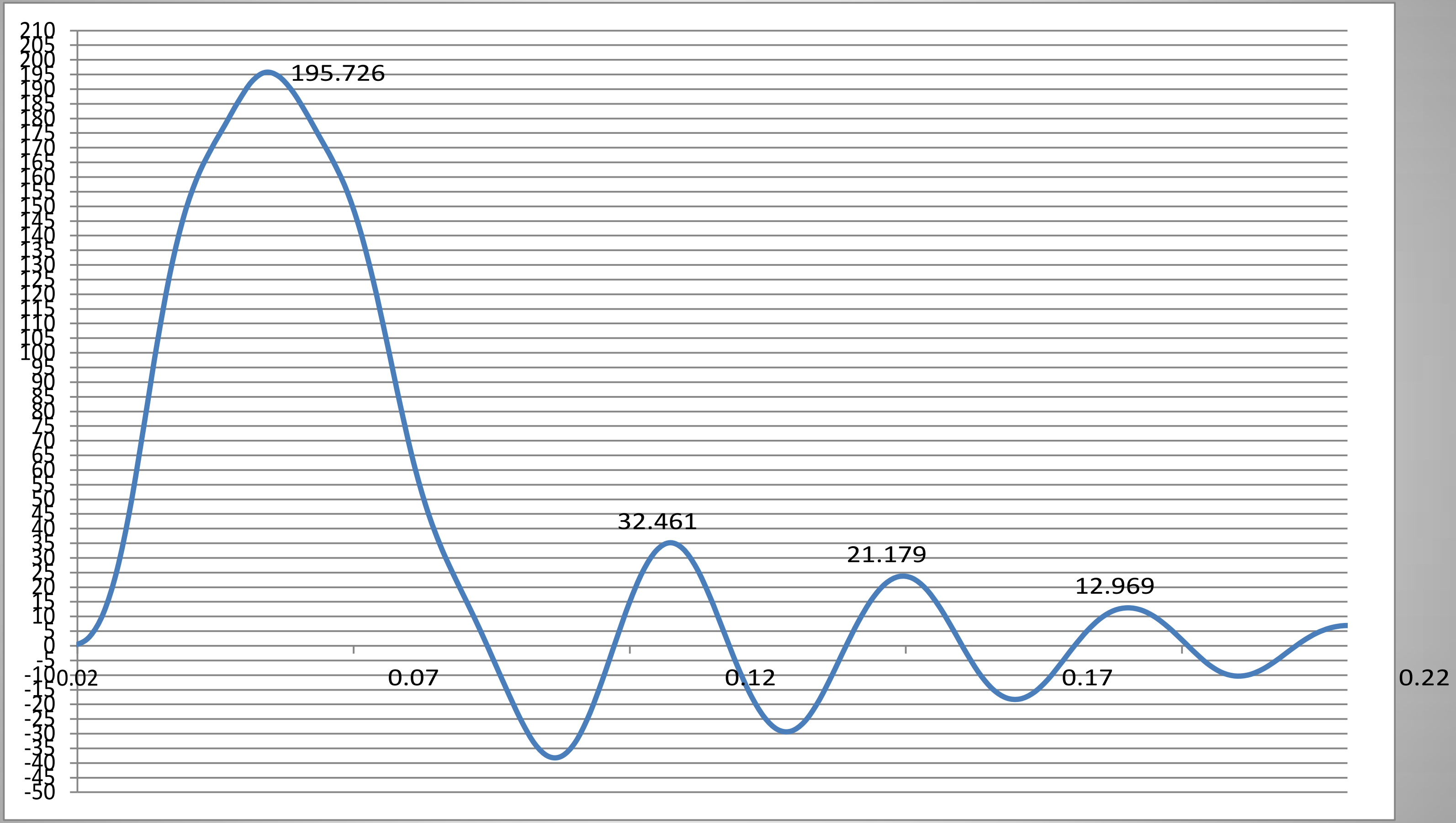
18 cycles over 0.594 seconds with a total of 1,540.442 newtons (346.305 pound-force) per ball hit. During a typical match this brand expells 277,279.56 newtons (62,334.925 pound-force) to your arm.

BRAND 4



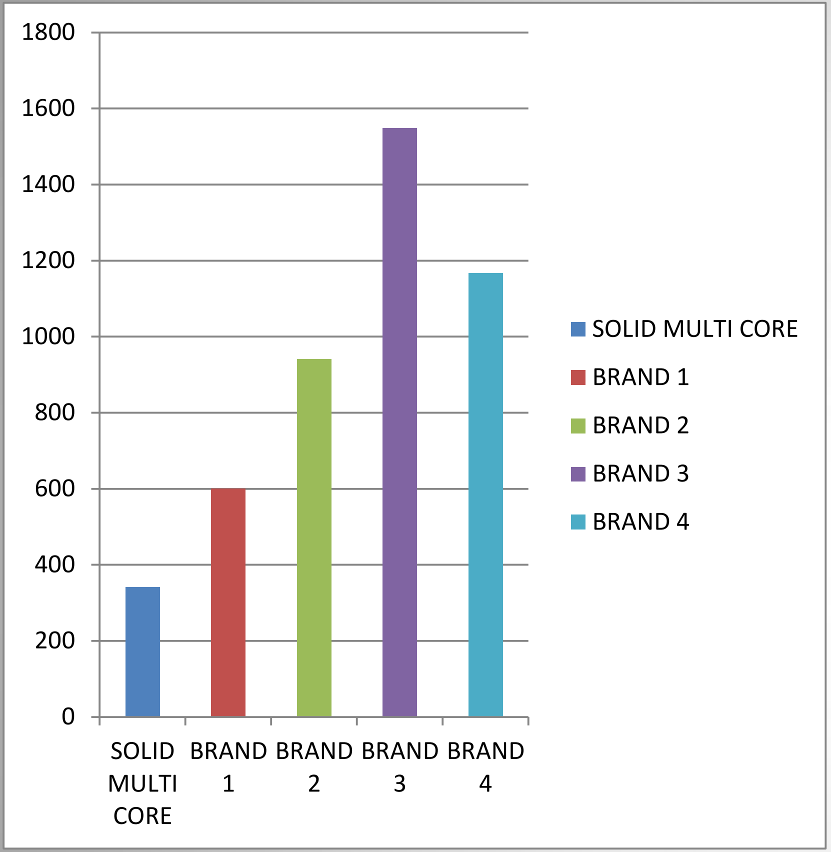
16 cycles over 0.584 seconds with a total of 1,172.218 newtons (263.525 pound-force) per ball hit. During a typical match this brand expells 210,999.24 newtons (47,434.516 pound-force) to your arm.

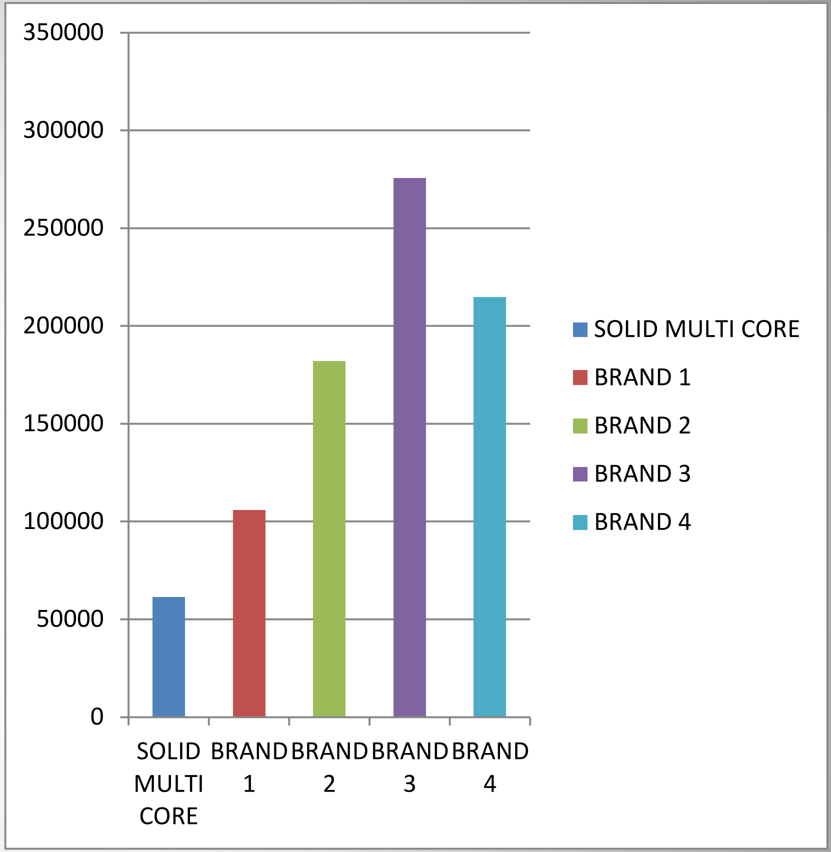
SOLID MULTI CORE



4 cycles over 0.16 seconds with a total of 341.13 newtons (76.689 pound-force) per ball hit. During a typical match this brand expells 61,403.4 newtons (13,804.033 pound-force) to your arm.

SHOCK AMPLITUDE





PER BALL HIT **PER MATCH**

An average air molded racquet expells 1,067.955 newtons (240.086 pound-force) to your arm during a single ball hit compared to 341.13 newtons (76.689 pound-force) a solid multi core racquet expells during a single ball hit. This can be extrapolated to a typical match of 180 ball hits. The results of which would be that an average air molded racquet would expell 192,231.9 newtons (43,215.450 pound-force) to your arm during a typical match where as a solid multi core racquet would expell 61,403.4 newtons (13,804.033 pound-force) to your arm during a typical match. Over 3 times lower.

METHODS

A 2.5lb weight dropped 18" along a guide to precisely hit the center of each racquet head. This is equivalent to an 80 mph tennis ball (see chart on next page).
Only one bounce (shock force) was allowed for the weight. The weight did not experience a repeat hit to the center of the racquet.
The center was measured for each racquet head, so it was comparable between racquets with heads of different sizes
The grip was mounted to a load cell on a calibrated MTS materials test machine
Since each grip varied, the grips were all mounted to the load cell in the same consistent fashion with the butt end of the grip in line with the edge of the load cell, the exposed grip to the center of the racquet head was measured for every racquet tested
Tests were run for each racquet and the load vs. time continuously recorded
Data was sampled at a rate of 250Hz.
The distance from the center of the racquet to the exposed grip was measured for each racquet mounted.
The load was directly read from the grip mounted to the load cell
All rackets were strung with synthetic gut and similar tension

BALL IMPACT FORMULA

Time of Impact velocity		
t = Sqrt(2*d/g)		
d	18	in
	0.46	m
g	9.8	m/s
t	0.3	s

Velocity of impact	
1.52	meters/second
3.35	miles/hour

Mass of Tennis Ball		Mass of Impactor	
50	grams	1135	grams
0.11	pounds	2.5	pounds

Velocity of Tennis Ball		Velocity of Impactor	
80	mph	3.4	mph
35.7	meters/second	1.55	meters/second

Momentum of Tennis Ball		Momentum of Impactor	
Mass* velocity		Mass* velocity	
1.79	kg*m/s	1.75	kg*m/s

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Procedia Engineering 60 (2013) 397 – 402

Procedia Engineering

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6th Asia-Pacific Congress on Sports Technology (APCST)

A mechanical study on tennis racquets to investigate design factors that contribute to reduced stress and improved vibrational dampening

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Received 20 March 2013; revised 6 May 2013; accepted 3 June 2013

Abstract

There are a multitude of factors that will affect the mechanical performance and stress transfer to a tennis player's upper extremities. Variations in frame design, materials, string tensioning, ball stiffness, impact locations, and player technique are just some of the potential variables that can result in a significant increase or decrease of stress transfer and vibration from the racquet to the player. To better understand the significant contributing design factors that influence shock and vibration transmission to the racquet handle upon impact, such testing was conducted in a standardized and repeatable manner to evaluate and compare the shock and vibration patterns for multiple frame designs from a variety of high performing tennis racquets. Multiple racquet frame designs from six different manufacturers were mechanically tested in an ISO17025 certified third-party independent test facility by qualified mechanical and biomechanical engineers. A consistent mass drop technique was employed to provide controlled impact to the center of the head of each mounted racquet. The impact load and duration were plotted and a Fourier Transform Analysis was conducted on each data file. The results of this study showed statistically significant reductions in vibrational dampening time and lower vibrational amplitudes following the initial impact shock for the triple core designs. This evaluation provided consistent baseline comparisons for different handle designs in a manner that demonstrated multi-layered cores of the racquet handle performed better than hollow designs with respect to vibration and force attenuation.

Selection and peer-review under responsibility of the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University

Keywords: Tennis racquet; biomechanics, handle; stress transfer; vibration; dampening; shock

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1877-7058
Selection and peer-review under responsibility of the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University
doi:10.1016/j.proeng.2013.07.015

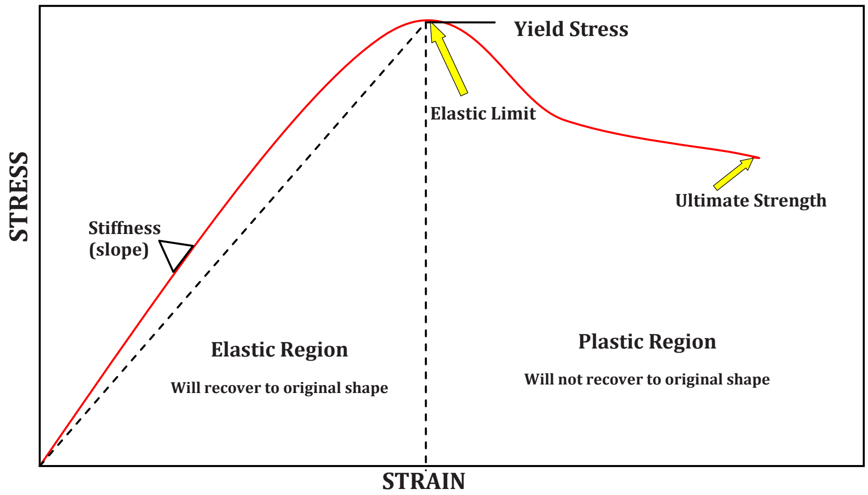
1. Introduction

Repetitive impact and overuse of the upper extremities in racquet sports can increase the risk of tissue fatigue and injury, leading to inflammation of the tendons and soft tissue in the wrist, elbows, and shoulders. Eventually, long term repetitive use can result in small stress fractures and chronic degeneration of the surrounding soft tissues due to microscopic tears that were incompletely healed [1]. There are many human factors such as; compromised muscular strength, poor technique, and increases in duration or intensity of play that may contribute to an increased risk of injury [2, 3]. Modern racquet designs have evolved to compensate for reduced muscular strength through the incorporation of stiffer racquets and harder tennis balls. However, an increased stiffness in the player's equipment can potentially lead to increased shock transmission from the racquet transferred to the tissues of the upper extremities (i.e. wrist, elbow, shoulder). Additionally, prolonged exposure to vibratory oscillations due to racquet displacement has the potential to lead to fatigue injury and tissue degeneration over time [2-4]. Recently, new and innovative technologies and materials have been incorporated into the handle designs of tennis racquets in an effort to reduce shock and prolonged vibration in an effort to reduce injury to the player.

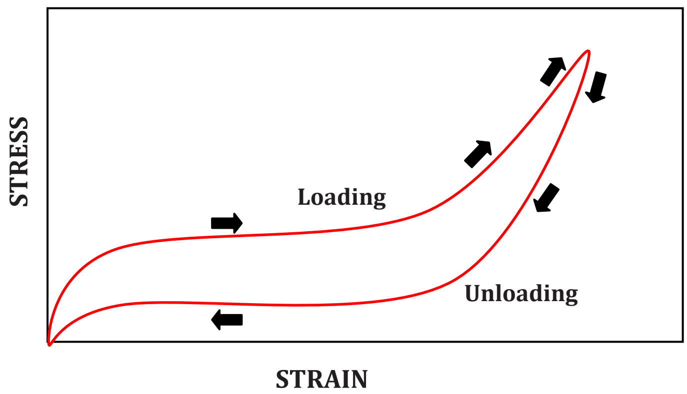
Numerous variations in racquet design, materials, string tensioning, ball stiffness, impact locations, and player technique are just some of the potential variables that when combined, can result in an exponential increase or decrease of impact, stress transfer, and vibration from the racquet to the player. The specifications of a tennis racket play a large part in how the tennis racquet performs. Racquet stiffness measures its flexibility along its longitudinal axis. The stiffness is measured in terms of a rating scale, with the majority of racquets ranging between 55 and 72 on the stiffness rating scale [5, 6]. It is measured by placing a specific amount of weight on a lever, which bends the frame. A stiffer racquet will transfer greater impact energy to the tennis ball, resulting in more power, while flexible racquets return less energy, resulting in less power. The stiffness of a racquet and its relationship with energy transfer is best explained by a stress-strain curve when a tennis racquet is loaded (Fig. 1).

The loading and unloading phase of a stress-strain profile generates a hysteresis curve that defines the mechanical performance of an object. Stiffness is measured as the slope of the stress-strain profile within the linear elastic portion of the curve. Therefore, when loading and unloading an object within this region, the object will undergo deformation and recover when unloaded to maintain its original shape. If an object is more compliant, greater deformation will occur during loading, resulting in a wider hysteresis curve and greater energy loss (Fig. 1a). The hysteresis curve is the sigmoidal curve generated from loading and unloading of an object (Fig. 1b). The area within this curve represents the energy loss. A wider curve represents greater energy loss and is indicative of an object with greater compliance or flexibility. A narrow curve is indicative of a stiffer object. If less energy is lost during the loading and unloading of an object, the hysteresis curve would be narrow when compared to the current graph shown in Fig. 1a. If less energy is lost, the remainder of energy will be directly transferred to the object, thus resulting in higher stress transfer to the object. In essence, a stiffer racquet that has less energy loss will transfer higher stresses from the handle to the tissue gripping the handle. Furthermore, a stiffer racquet will transfer greater impulse forces (shock) [5, 6] to the human tissue, and higher vibratory amplitudes. Lower amplitudes and shock forces indicate greater flexibility.

Many studies have investigated a combination of these variables to quantify shock and/or vibration for a variety of racquet designs. However, variations in the literature exist with respect to study design where controlled comparative studies were difficult to perform, included a multitude of variables that may have masked the study outcomes, and may have provided conflicting or inconclusive comparisons. To better understand the significant contributing factors towards stress and vibration transfer for different tennis racquet frame designs, such testing was conducted in a standardized, consistent, and repeatable manner to provide statistically valid comparisons with minimized variability in the study design. Therefore, the goal of the present study was to provide an initial mechanical evaluation of shock and vibration for multiple frame designs from a variety of high performing tennis racquets to investigate potential design factors that could influence shock and vibration transmission to the racquet handle upon impact. In order to provide a direct comparison between racquet handle designs, the testing conducted was controlled in a manner to isolate specific design factors and eliminate the effects of string material and tension.



(a)



(b)

Fig. 1. Relationship between stiffness and energy through stress-strain curves (a); Typical hysteresis curve (b)

2. Materials and methods

Ten racquet frame designs from five different manufacturers were mechanically tested in an ISO17025 certified third-party independent test facility by qualified mechanical and biomechanical engineers. To minimize variability and provide a well-controlled comparison between tennis racquets, a consistent mass drop technique using a calibrated mass along a drop guide mounted to an electromechanical materials test machine (MTS Corp. Eden Praire, MN) was employed to provide accurate repetitive impact to the center of the head of each mounted tennis racquet. The center was determined through direct measurements and marked for each specific racquet tested. Each racquet handle was secured to a load cell (maximum capacity of 5kN) via gripping plates such that the face of the racquet was perpendicular to the mounted handles. A 2.5lb (11N) weight was dropped at 18 inches (0.46m) with a mean acceleration of 24G's onto the marked center of each racquet for five trials of impact. The mean acceleration of 24 G's for a stationary racquet with a mass drop in this study was slightly less than the 26G's of acceleration measured for a racquet in swing motion impacting a tennis ball with a collision duration of 5ms [6].

The specifications for each racquet, string tension, total handle length, and exposed handle length from the fixed edge of each mounted racquet were recorded. To minimize variability for consistency, the exposed handle length was maintained within the same ratio with respect to the total handle length for the different manufacturers and the string tensions were set to manufacturer specifications. The results were evaluated between racquet handle designs for both normalized and non-normalized of the parameters to the string tension for providing an equilibrated direct comparison. Normalization of each racquet's measured parameter (peak force) were divided by its string tension and statistically compared. This was conducted to remove the variability created by the slightly varied string tensions between tennis racquets for statistical comparisons. The composition and design of each handle was also documented and necessary for the comparative analysis. There were three different types of handles designed (triple core, dual core, hollow) and are outlined in Table 1, which detail the specifications for each racquet type. The internal core designs of the handle were categorized as the triple core, dual core, or hollow design.

Force and dampening times were compared with and without normalization to the string tension. Furthermore, the mounting of the racquets and design of the study minimized such variabilities due to the consistent nature of the test design. Each racquet handle was mounted and rigidly affixed to a calibrated load cell mounted to a materials test machine. The length of the exposed handle to the marked center of the racquet head was measured and the ratio of exposed length to total length to the center was maintained for all of the racquets tested. Five impact tests per racquet were performed. The impact and vibratory forces and duration were continuously sampled using MTS Testworks Software and a Fourier Transform Analysis was conducted on each data file sampled. This allowed for the full sinusoidal oscillation patterns to be sampled and the force at impact, force for each vibration, and time to dampen to be analyzed. The Fourier Transform generated the time domain and frequency domain for each sample. Minimizing variability from the impacting element, impact location, and the string tension in the manner described above allowed for a direct comparison between racquets to better determine the contributing factors towards stress reduction and vibration dampening from the handle of the racquet to the player. The time domain, initial impact force and vibratory forces transferred to the handle, and vibratory duration (time to reduce oscillations to a negligible force <5N) were analyzed. Dampening was considered complete when the vibrational amplitudes (in terms of force) were less than 5N. A one way Analysis of Variance (ANOVA) to a confidence interval of 95% and paired two-tailed t-tests were conducted to identify differences between the racquet handle designs.

Table 1. Racquet parameters categorized by handle design

Racquet Number	Material	Handle Design	Stiffness Rate
1	Carbon Fiber	Triple core	61
2	Graphite	Dual core	63
3	Carbon Fiber	Triple core	57
4	Graphite	Dual core	64
5	Graphite	Dual core	61
Mean (Stdev)			61.2 (2.7)
6	Graphite w basalt planks	Hollow	68
7	Graphite Tungsten	Hollow	67
8	Graphite	Hollow	70
9	Graphite	Hollow	67
10	Graphite Tungsten/Copper/Titanium	Hollow	65
Mean (Stdev)			67.4 (1.8)

3. Results

Table 1 showed that the stiffness per the manufacturers' specifications between the racquet types were lower for the core handle design group when compared to the hollow handle. Statistically the dual and triple core racquets were significantly less stiff than the hollow racquets ($p<0.05$) as shown in Table 1. The time to dampen the vibrations was greatest for the hollow racquets. Contrary to this, the triple core demonstrated the shortest dampening time with respect to the vibratory oscillations. Additionally, the hollow racquets demonstrated greater peak force (shock) than the triple and dual core, with the triple core demonstrating the fastest vibration dampening, lowest shock force, and lowest vibratory forces transmitted to the racquet handles (Figures 2a through 3a).

The Fourier Transform analysis demonstrated significant reductions in the vibrational dampening from the generated time domains for the core handle designs greater than the hollow designs. Additionally, the amplitudes during the vibration oscillations following the initial shock impulse for the core handle design were significantly less than that for the hollow designs, with the triple core handle design demonstrating the greatest decrease in amplitude after the initial shock force, $P<0.05$, (Fig. 2b). The hollow core design reduced shock force by 22%, where the core designs reduced the shock by at least 65% or more.

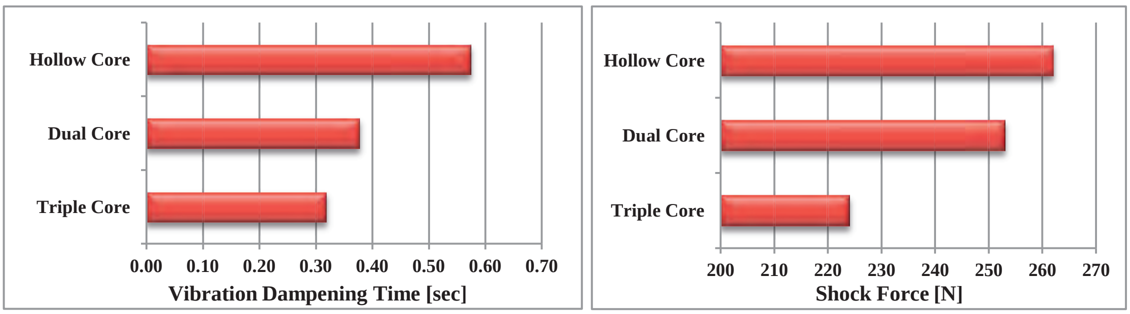


Fig. 2. (a) Mean vibration dampening time at impact for the handle design; (b) Mean shock force at impact for the handle design

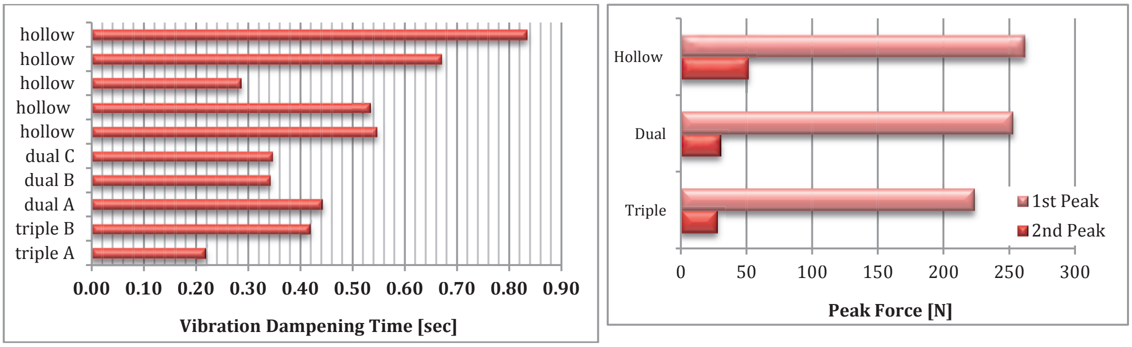


Fig. 3. (a) Vibration dampening times per racquet handle design; (b) Force difference between impulse and 2nd vibratory force

4. Conclusions

The dual and triple core designs demonstrated reduced dampening time where these designs successfully dampened the vibratory oscillations by at least 35% for the dual core and 50% for the triple core design when compared to the hollow handle design. Additionally, the amplitudes during the vibration oscillations following the initial shock impulse force for the core handle design were significantly less than that for the hollow designs, with the core handle designs demonstrating a reduction in these forces by at least 65% and the hollow core design reducing the shock force by 22% (Fig. 3b).

Overall, the dual and triple core designs demonstrated significantly lower shock forces and vibratory forces and dampened vibration quicker than the hollow designs. Although this study provided a controlled and repeatable assessment of racquet design, additional testing is currently underway to further investigate the impact of design factors that have the greatest capacity to reduce shock and vibration while replicating tennis swing kinematics and upon ball impact.

References

[1] Regan WD, Grondin PP, Morrey BF. Elbow and forearm. In: DeLee JC, Drez D Jr., Miller MD, eds. DeLee and Drez's Orthopaedic Sports Medicine. 3rd ed. Philadelphia, Pa: Saunders Elsevier; 2009:chap 19.

[2] William C. Whiting PhD; Ronald F. Zernicke PhD, Biomechanics of Musculoskeletal Injury, Second Edition ISBN-10: 0736054421, ISBN-13: 978-0736054423.

[3] Nordin M, Frankel, VH., Basic Biomechanics of the Musculoskeletal Skeletal System, 2nd edition, Williams and Wilkins, Lippincott, Philadelphia, PA, ISBN 0-683-30247-7.

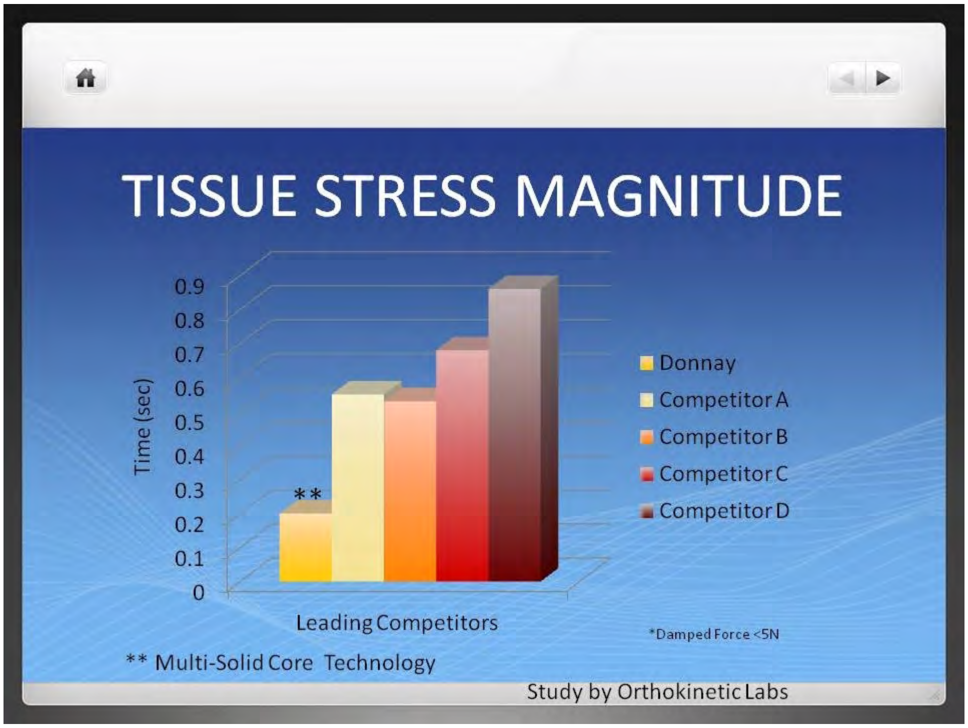
[4] Reynolds DD, Standlee KG, Angevine EN, Hand-Arm Vibration, Part III: Subjective Response Characteristics of Individuals to Hand-Induced Vibration, Jour. Of Sound and Vibration, 1977, 51(2); pp:267-282.

[5] Miller S, Modern Tennis Rackets, Balls, Br. J. Sports Med. 2006; 40:401-405, bjsm:2005.023283.

[6] Brody H, Cross R, Lindsey C, The Physics and Technology of Tennis, Independent Pub Group, April 2004, ISBN-13 – 9780972275903, ISBN-10-0972275908.

Tissue Stress Magnitude – An Independent Study In Search Of Arm Friendly Tennis Racquets

Over the years, Donnay has established a brand that focuses on producing arm friendly tennis racquets. I reached out to Donnay asking couple questions, about the methods, approach on design etc… when asked about the performance and a scientific stufy, they provided the independent study by Orthokinetic Labs, which Im posting below unedited.



The results of the first part of the first-ever independent Racket Shock & Injury Medical Study are in and they dramatically show that Donnay multi-solid core frames produce four times less shock & vibration time on ball contact than competitive hollow rackets from the four leading brands.

The study was conducted by OrthoKinetic Technologies, LLC, a leading independent firm in Shallotte, NC, that tests medical devices for regulatory and pre-clinical test strategies for FDA and CE submissions.

The Donnay racket, engineered for Arm Safe Performance, vibrated for less than 1/5 of a second on ball contact in the test, compared to an average of 7/10 of a second for the other models tested. That means a player hitting 180 balls in a typical tennis match is subjected to more than 111 seconds of shock & vibration dwell time with the other brands versus 32 seconds with the Donnay.

The importance of the study to players: They get a vibration every time they hit the ball and some of the shock is transmitted to the arm. The more prolonged the shock & vibration the more it can cause arm injuries. Results of the second part of the study – the amount of initial shock & vibration between Donnay and the other brands will be released next week.

The extent of frame vibration transmitted to the arm holding the racquet depends largely on how well it is dampened. Donnay's solid-core XeneCore construction and manufacturing process acts as a super dampener to eliminate most all of the damaging vibrations.

In the old wood rackets, vibration disappeared quickly because it was dampened by the flex of the solid wood, but the new stiffer, lighter and hollow conventional frames do a poor job of snuffing out the vibrations, so they transfer this shaking to the arm that can stealthily sabotage the elbow, wrist, forearm and shoulder. The longer the vibration and the longer a player rallies the more the tendons are stressed. This constant stressing is how a coathanger is broken by bending it back and worth. Eventually, fatigue can cause tissues to snap, even without any tremendous force.

Hollow racquets with their poor dampening properties cause pain (think of hitting a baseball with the hollow aluminum baseball bat on a chilly day).

For years the tennis industry has laid the blame for arm injuries on poor stroking techniques, conveniently diverting scrutiny from the design of racquets, but hollow, stiff, ultralight head-heavy racquets are more to blame. As conventional racquets have grown lighter and stiffer the number of players suffering from arm and elbow pain has also risen dramatically. The cause is no longer primarily related to mechanics, but rather to the equipment itself.

In addition to Donnay's solid-core technology and consistent with its mantra of "Arm Safe Performance," Donnay's specs reflect more arm-friendly properties that include more mass, head-light balances and flexible frames.

The release of the first part of the study, entitled "Tissue Stress Magnitude," is great news for your retail dealers since as many as one-in-four of their customers are currently experiencing some form of arm pain and are looking for racquets that help them recover quickly or play through the pain. That's when power and control take a backseat.

Because if you're trying to play hurt, you're not playing well at all.

Best wishes for the holidays and we'll keep you breast with the rest of the study, along with a detailed report from next week from OrthoKinetic Technologies.