WHITE PAPER

Towards Trampolines Without Injury

Summary

Trampolines have been with us for almost 70 years. As their popularity has increased, so have the injury statistics. Until recently the solution to managing impact risks has been to supply add-on padding, rigid-pole barriers and a profusion of warnings.

The patented SoftEdge Technology (SET) developed by SpringFree Trampolines had a "Zero Impact Zone" target. It is the result of the first genuine engineering effort designed to remove all sources of impact injury from the domestic trampoline.

Introduction

In 1908 Henry Ford shipped the first mass produced automobile, the Model T. Compared to today's automotive technology, it would not be considered "fit for purpose". Technology has moved on.

In 1938, Boeing built the first commercial airliner, the Boeing 314 Clipper flying boat. Compared to today's aeronautics technology, it would not be considered "fit for purpose". Technology has moved on.

In 1935, George Nissen invented the first commercial trampoline. Amazingly, compared to today's mainstream trampoline technology, there has been virtually no change. What is essentially the same design is still being manufactured and is still considered 100% "fit for purpose". Sadly, trampoline technology, unlike almost every other popular consumer device, has remained frozen in time—until now.

Figure 1: Potential injury from conventional trampolines

A careful analysis of worldwide trampoline injury data initiated in 1994 by Dr Keith Alexander (University of Canterbury, Christchurch, New Zealand) revealed that in order to build a safer trampoline three major impact zones would need to be engineered out of the traditional design:

- The springs, which were in the same plane as the jumping surface
- The steel frame, which was also dangerously close to the jumping surface
- The ground or obstructions on the ground, which could be hit as a result of jumpers falling off the trampoline altogether

After 11 years of design, materials innovation, prototyping, and the application of significant international venture capital, SET Technology (SoftEdge Trampoline) is bringing trampoline technology into the 21st century.

Technical Evaluation and Design Review

The best way to remove hazards is to design them out completely. This is always superior to providing guards, pads or warnings. In order to remove (and not just attenuate) each of the impact zones

identified in conventional trampoline design, a whole set of novel engineering strategies needed to be developed and tested. Designs were roughed out, prototyped, tried, patented, and then thoroughly field-tested over a number of years. The final result is an integrated set of sub-assemblies that in concert, remove all the impact zones inherent in the traditional design, and deliver the world's safest trampoline. A detailed description of the principal design considerations follows:

The Edge

There are a number of design issues with the edges of conventional trampolines. Because they are constrained in having a frame and springs around the edge of the jumping surface, the safety goals have been to:

- Protect the jumper from falling through the holes between the springs
- Protect the jumper from hitting the steel frame
- Prevent the jumper from falling off entirely
- Protect the jumper from combinations of the above
- Do this at a low cost

Conventional solutions have been to provide padding that is intended to both:

1. Cover the springs to prevent injury from the springs themselves and stop jumpers from falling through the springs;

2. Cover the frame with impact attenuation material to prevent injury from falling on the frame.

These solutions have had limited success because:

- Padding material is costly so a minimal thickness of padding is used – frequently less than will meet the standards[1].
- Unless covered with a fabric the padding is not strong enough to stop falls through the springs (Figure 2).
- Unless large enough it does not adequately cover the frame (Figure 3).
- Unless thick enough it does not provide adequate protection from the steel frame
- Due to cost considerations the industry standard choice of foam loses its impact absorbing properties after more than 3 impacts on the same spot.
- Unless well anchored it moves and fails to cover the rails (Figure 4).
- It needs to be robustly weather-resistant to function over a reasonable time.

Figure 2: Unless strong enough, padding will not prevent falls through the springs.

Figure 3: When the vinyl flap is lifted, it can be seen that the padding does not extend its protection over the frame.

Figure 4: Unless anchored adequately, padding will move and will not prevent impacts with the frame.

[1] Compliance with existing international standards still allows for serious injury. See Table 2 (Page **8**).

- Because the option is open, many customers will not even invest in padding.
- To provide protection over time, some form of preventative maintenance must be in place – not common in most backyards.

SoftEdge Trampoline Concepts

Given these built-in limitations to improving the safety of conventional trampolines, an effort was made to re-engineer the trampoline to remove the springs and frame from the jumping surface. Over a number of years more than 10 concepts were investigated, four were built and one chosen for further commercial development.

Ultimately the rod-type trampoline of Figure 7 was believed to provide the best mix of characteristics. After systematic investigations of five rod material options, a pultruded composite was chosen as the most promising for strength, weight and cost. After average results in early consumer tests the material scientists developed a proprietary high performance composite design, tailor-made for this application. The final result is a consistent, non-corroding, trouble-free, resilient suspension system.

Care with Pultruded Fiberglass Composites

The springs in conventional trampolines need protection. They are zinc plated to protect against corrosion, the cut ends need to be inaccessible and the springs should be covered with padding to prevent pinching and entrapment of jumpers.

The pultruded fiberglass rods of SpringFree trampolines also need appropriate consideration. Like many high tech materials the SpringFree composite must be treated properly. The matrix is a plastic and as such, is slightly susceptible to UV light. Also, it can be damaged by hard objects, such as wheelbarrows, bikes and garden tools. If the matrix is allowed to deteriorate with UV, fine fibers come free and these can cause irritation when exposed rods are handled.

For these reasons these high tech rods are enclosed in UV-resistant polypropylene sheaths (patents pending). These protect the rods from mechanical damage and UV light as well as ensuring lifelong trouble-free handling. The sheathing is shown in Figure 8.

How the SpringFree rod-based trampoline works

The rods in a rod-based trampoline are like fishing rods (in fact, they have some common materials). They are placed in sockets in the rigid frame as shown in Figure 7. To connect with the mat, the ends of the rods have to be bent inwards towards the center. The force needed to bend them inwards is the force that keeps tension in the mat. So the mat is tensioned just like the mat of any other trampoline.

Figure 5: The first unit built for customer trials.

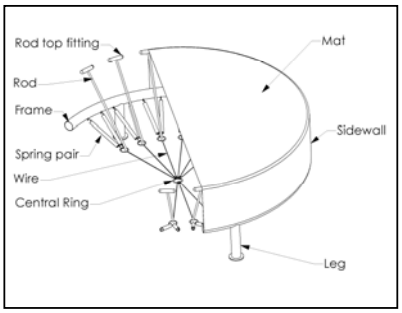

Figure 6: The second concept, built for trials and commercial assessment. *(reported in Proc Instn Mech Engrs, Vol 215, Part B P589)*

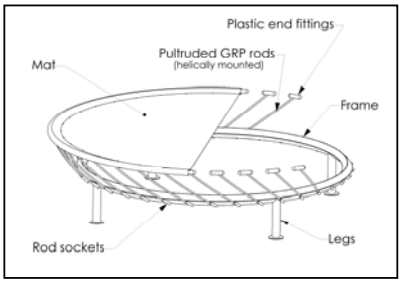

Figure 7: Schematic of the final concept model built for trials and commercial assessment

Figure 8: SpringFree high-tech composite rods are encased in a patented polypropylene sheath arrangement, providing mechanical and UV protection, and trouble-free handling.

Edge Landings

The trampoline is designed for people to land safely on the edge. The rods are laid over at about 30 degrees (see Figure 7) so if someone lands on the edge, the rod below is deflected down, pulling its neighbours with it. The effect is that the edge behaves like a safe, flexible and resilient rim to the mat. (See also Figure 13; patents pending on the edge performance)

Does the jumping surface twist during use?

This question is only asked by people who have never tried a rod-based trampoline. Certainly the unit looks as if it would twist during a bounce. But as predicted by the original designer, the effect is undetectable in normal use. Even when jumpers make heavy bounces right on the edge, the twist is not something they notice or mention. Figure 9 and a brief calculation will show why this is.

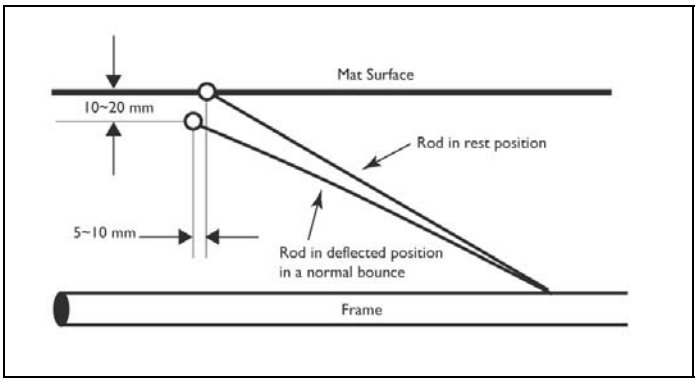

Figure 9: In a normal bounce, the mat edge moves circumferentially about 5 to 10 mm.

During a normal bounce the mat edge moves primarily in and out from the mat center, by about 25 to 50 mm. It also moves up and down by about 10 to 20 mm. Because of the rod's 30-degree angle to the horizontal, this up and down movement means it moves laterally (to the left in Figure 9) by 5 to 10 mm as shown. This means the edge moves around about one-sixth to one-third of a degree. To put this in perspective, if the trampoline mat is considered as a clock face, this is equivalent to the distance the minute hand moves in 3 seconds. (Not the second hand, the minute hand!)

In other words, the twist is all but undetectable, especially when bouncing. So in practice, with the enclosure in place the twist is simply not registered.

Figure 10: Plastic cleat ball-and-socket system for rod attachment to the mat edge. The clip (red) and the ball (blue) are shown separately.

Edge Connections

The connection between the rods and the mat required considerable development work and resulted in several patents. Over 10 plastic cleat designs have been built and tested in the process. Over 5 mat edge designs have been fabricated during the course of customer trials.

The current cleat design is shown in Figures 10 and 11. It has the following features:

- The cleats have a large flat top face to provide a safe landing surface at the rod end.
- Long loading edge to spread the load into the mat edge and reduce wear points
- Permanent connection between the rod and the ball
- Ball and socket joint that captures the rod end but allows freedom of movement
- Retaining clip that ensures the ball cannot be released from the socket inadvertently
- The retaining clip requires no action during assembly, but with a deliberate movement of the lever it allows ready release during disassembly.
- Cleat of a high stiffness UV-resistant material designed to outlast the mat
- The cleats are sewn into the mat at the factory and are simply clipped on to the rods during assembly of the trampoline by the customer.

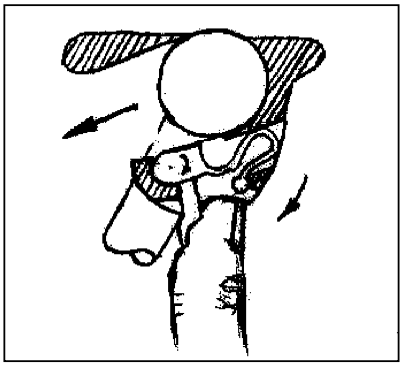

Figure 11: The release system for disassembly.

The current mat edge design is shown in Figure 12 and has the following features:

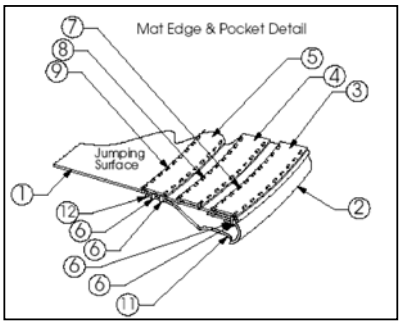

Figure 12: Mat edge detail (patent pending).

- The cleats are sewn into the edge during manufacture.
- The load-bearing part of the edge is a tough webbing material that is ideally suited to the heavy duty required at the rod-mat interface.
- Mat structural stitch-lines are traditionally the first part of a trampoline to fail. In SpringFree trampolines there are 5 stitch-lines contributing to the mat edge support.
- Because SpringFree trampolines do not require edge padding, contrasting colour is sewn into the mat edge in the form of coloured webbing bands.
- The main structural stitch-lines are covered with these webbing bands, giving UV and mechanical protection, ensuring a longer life for these vulnerable threads.

Injury Statistics for Trampoline Edges

There have been a number of studies and sources of statistics. They give broadly the same picture. In one fairly representative and concise Australian study the results of reported trampoline injuries in Queensland were:

Table 1: Summary of Trampoline Injury Statistics

Cause	Percent
Fall off of trampoline	52%
Fall onto the frame or springs	31%
Hit another child on the trampoline	17%

A review of the on-line data from the US Consumer Product Safety Council (www.cpsc.gov product code 1233) indicates roughly the

same results, but also highlights many "self-inflicted" injuries such as neck strain from landing on the head, or ankle sprain from landing awkwardly on the mat.

Head Injury Criterion (HIC) and the Severity Index (SI): Measurements that give a Safety Rating

The HIC and SI are laboratory-determined numbers, which give a statistical probability of injury on impact surfaces for a specific set of test conditions. They are useful as a benchmark because they allow safety comparisons to be made between different impact surfaces. The SI is the older measure (still used by some standards) but superseded by the HIC. The HIC will be discussed here, and by way of example, figures are given in Table 2 below to illustrate what it means.

Table 2: The meaning of the HIC (Head Injury Criterion) [2]

Test: In a free fall from 1.5m the head strikes the test surface. The HIC number indicates the level of injury likely to result from an impact on that surface, as shown below.					
Head Injury Criterion (HIC)	Chance of NO Injury	Chance of Minor Injury	Chance of Moderate Injury	Chance of Critical Injury	Chance of Fatality
77*	Over 99%	Under 1%	~0%	~0%	~0%
250	65%	35%	12%	~0%	~0%
400**	30%	75%	30%	Under 1%	~0%
1000+	1%	99%	90%	3%	~1%
2000	~0%	100%	100%	65%	25%
		Skull trauma; no loss of consciousness; fracture of nose or teeth; superficial face injuries	Skull trauma; brief loss of consciousness; fracture of facial bones; deep wounds; possible dislocated skull fracture	Cerebral contusion; loss of consciousness for more than 12 hrs with intracranial hemorrhaging and other neurological signs. Recovery uncertain.	

* SpringFree trampoline edge HIC as measured by independent laboratory (SF90E)
** Traditional trampoline HIC with a 70 mm pad of closed cell foam over the frame. (Note: This is 3 times the thickness of most trampoline pads sold).
+ HIC allowed by trampoline standards

The Head Injury Criterion was developed in the automotive industry. It has been adapted for use in other areas, in particular

---

[2] This table is based on data developed from:

1. National Highway Traffic Safety Administration (NHTSA), Department of Transportation., 1997, FMVSS201, Head Impact Protection, 49 CFR 571.201.
2. Prasad, P. and Mertz, H. J., "The Position of the United States Delegation to the ISO Working Group on the Use of HIC in the Automotive Environment," SAE Paper No. 851246, Society of Automotive Engineers, Warrendale PA, 1985.

playground surface requirements. The playground "safe surface" requirement is that the HIC should be less than 1000 (see Table 2). The reason for the choice of HIC 1000 was because beyond this level the chance of a fatality from a fall was beginning to become significant at the 1% level. In other words the standard-setters wanted a standard that would prevent deaths from falls in playgrounds. While fatality might be prevented it can be seen that at HIC 1000 there is still significant risk of severe, possibly disfiguring or debilitating, but survivable injuries.

Because of its acceptance for playground surfaces, trampoline standard-setters have chosen the same HIC values as suitable for the padding over steel trampoline frames. This means that trampoline standards aim to prevent death from head impacts with the padding covering the frame, while they accept the significant chance of moderate and critical but survivable head injuries.

While the HIC has been developed specifically for head injuries it does not say anything about other types of injuries such as the more common fractured limbs.

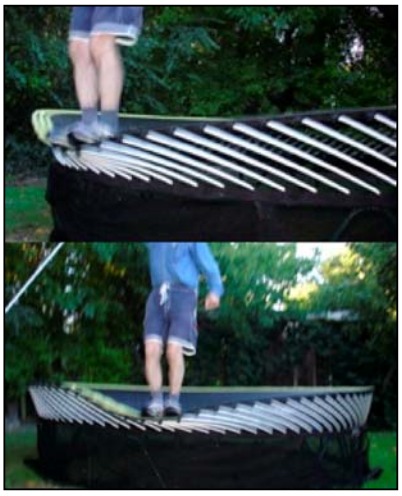

Figure 13: The SpringFree Trampoline edge; landing a jump.

SpringFree Trampoline Edge Performance – SoftEdge Technology (SET)

The SpringFree trampoline design has removed the frame and springs from the jumping surface, placing them safely out of the impact zone. The design is such that the edge stiffness can be tuned to meet requirements. It has therefore been tuned to achieve what SpringFree believes to be a safe and acceptable performance. In comparison with conventional trampolines the mat edge replaces the pad-covered springs and frame.

- Currently the Standards require the pad-covered frame of conventional trampolines to have an HIC value of less than 1000 (many backyard trampolines on the market exceed this and so do not comply with the standard).
- The edge of a SpringFree SF90E trampoline has an HIC value of 77 (tested in an independent laboratory).
- The edge of a SpringFree SF40E trampoline is considerably less than 77 .

By contrast Table 2 shows that for HIC 1000, (the value accepted by the standard) significant injury is virtually guaranteed for the same test conditions. (99% chance of minor injury, 90% chance of moderate injury; 3% chance of critical injury).

This means that if a child were to fall from 1.5 m and strike their head on the padded frame of a conventional trampoline they would have a 99% chance of a fractured tooth or broken nose, and a 90% chance of something worse. But if they were to have the same fall on to the edge of a SpringFree trampoline they would have a 99% chance of no injury at all.

These results are measurable evidence of the improvement the SpringFree design has been able to achieve. They validate the

SpringFree philosophy and the engineering that has gone into designing a safer trampoline. By way of illustration Figure 13 shows the effect of landing on the edge of the SpringFree trampoline.

SpringFree's Claim to Being the Safest Trampoline

Results of research into the cause of injuries (Table 1 above) show that about 52% of hospital visits from conventional trampolines result from falling off the trampoline altogether. Because SpringFree has made the enclosure an integral part of its design and only sell the trampoline with an enclosure, there is little chance that injuries will result from people falling off.

Table 1 shows that 31% of hospital visits arise from contact with the springs or frame. Since the SpringFree trampoline does not have springs and holes around the edge, there has to be a complete absence of injuries from springs, from falling though the holes between them or from sliding into them under the padding.

And given the very low HIC values in Table 2 above one would expect an almost 100% reduction in the types of injuries caused by contact with the frame or edge. The table implies it could be less than 1% of the present injury rate.

Table 3: SpringFree's effect on trampoline injury statistics

	Current	**SpringFree**
Cause	*Percent*	*Percent*
Fall off trampoline	52%	~0.5%
Land onto springs or frame	31%	~0.3%
Hit another kid on trampoline	17%	17%
Total	100%	18%

These points are summarized in Table 3 above. This shows that the SpringFree trampoline has the potential to reduce injuries from contact with the trampoline itself, or with the ground to about 1% of the current reported levels. The remaining risk of injury is primarily that resulting from inappropriate use where multiple jumpers strike each other.

One final point is that the SpringFree mat is intentionally softer than many others on the market (See "Mat Stiffness" below). A large number of minor injuries in the databases are strains and sprains. This large number suggests that there will be many more that go unreported. While there are no definite statistics it seems evident that a softer mat will reduce the number of these lower grade injuries.

So in conclusion, the SpringFree claim to be the safest trampoline would seem to be very well supported by recent available evidence.

Figure 14: Two types of enclosure: Net outside the frame (top) and net inside the safety pads (bottom).

Enclosures

The enclosure is a netting barrier structure that prevents people from falling off a trampoline and on to the ground or on to another obstruction. Several types of enclosure are shown in Figure 14.

Figure 15: On a conventional trampoline the net catches the jumper and guides him down to impact ot the steel frame, which is often not adequately padded. (Note: For this photo, the user prepared the impact area on the frame by installing several layers of white padding.)

Enclosure Injury Statistics

As a result of the research noted in Table 1 above, there has been an increase in the sales of (a) aftermarket enclosures (b) trampolines sold complete with enclosures. Thankfully, in the most recent accident statistics, this appears to have resulted in a reduction in reported trampoline injuries.

At this point it is too early for there to be reliable statistics on injuries resulting from enclosures themselves, but these figures are becoming available. For example a 32-year-old man is reported to have broken his nose on impact with an enclosure post, most likely one similar to those shown in Figure 14 above.

Enclosure Risks

Conventional enclosures, as shown in Figure 14, unfortunately introduce several new risks:

- As just noted, the jumper may hit the pole that supports the net.
- The jumper may hit the net and then be guided down only to fall on to the steel frame below (See Figure 15). This can occur whether the net is inside the safety pads (as in Figure 15) or outside the frame (as in the first picture in Figure 14).
- The jumper may come down on to the top of a pole.
- The net attachment may not be applied correctly by the customer (some net attachment procedures are quite complicated).
- The net attachment components may deteriorate over time so that they fail and the net ceases to work effectively (there has been a recent enclosure recall of over 1 million enclosures for this reason).

While these design failures still reduce the risk of injury to levels lower than falling off the trampoline altogether, they continue to expose the jumpers to risk, and still need to be adequately addressed for user safety.

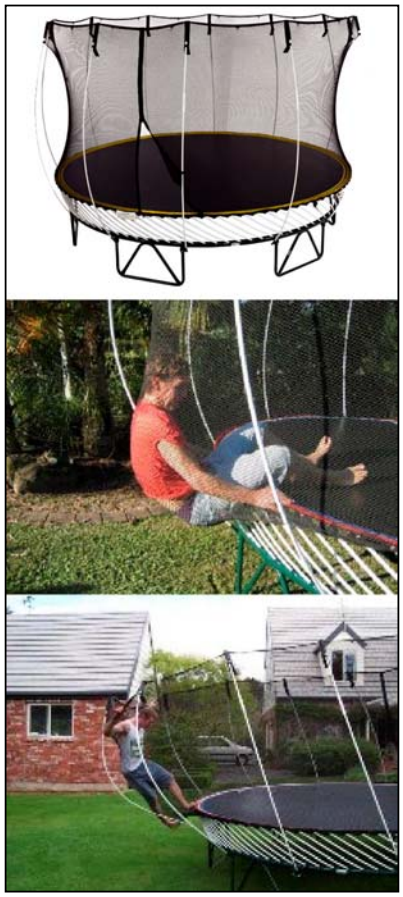

Figure 16: SpringFree FlexiNet enclosure; the landing is in the net or on the soft edge of the mat shown in *Figure 13*.

The SpringFree Enclosure

The SpringFree enclosure, as shown in Figure 16, was designed not as an afterthought or band-aid, but as an integral part of the whole concept. The design goal was a system able to deliver uniform plastic deformation in all planes. Like the mat edge, it was intended to provide a soft and safe surface for all points of impact. With this in mind it has the following features:

- While it is sold as a safety feature, the engineers were instructed to design it as a fully functional, auxiliary play surface, with adequate softness and rebound for vigorous activity.

- Any falls into the net only land the jumper on the soft mat edge (shown in Figure 13), rather than on to the steel frame (shown in Figure 15 and Figure 3).
- The supports are high tech composite rods, bent like fishing rods to tension the net. These are all but unbreakable even in misuse (see Figure 17).
- Each individual support rod is bowed away from the net and is too flexible to inflict injury even if it is reached by a jumper
- The support rods are interconnected as a set, and working together, create a dynamic resilient structure strong enough to cushion the heaviest jumper.
- Because the rods are bowed on installation, the ball-ended tip is safely flexible should a jumper come down on it. It does not need an extra buffer.
- The soft net, tensioned by the rods, has a small mesh so that fingers cannot get caught in it.
- During assembly the net is attached at the bottom to every rod, through specially provided holes in the tough bottom band. No cords or straps are used in assembly.
- The door, being a zippered opening is easy to understand, easy to enter, easy to open and close and it can even be padlocked to control who uses it. (Figure 18)

Figure 17: Enclosure rods are strong enough for extreme misuse.

Enclosure Requirements in the Standards

The standards place requirements on enclosure components in order to maximize the safety and minimize some of the newly introduced risks noted above. These standard requirements are in part:

- To ensure the net system is large and strong enough to perform its function without deterioration (unlike the system in Figure 15)
- To put padding on poles to prevent injury from impact against them (Figure 14)
- To put suitable buffers on the tops of poles to prevent impalement (Figure 14)
- To avoid sharp hooks or catches

Figure 18: Canadian Olympic trampoline medalist, Karen Cockburn, stands at the zippered door for the launch of the SF40E (8 ft) trampoline.

Clearly the main objectives of the standards have been to make the enclosure a robust and effective safety device. But the standards have been developed from the perspective of enclosure technology available in the market at the time they were written.

The target for the engineers at SpringFree was to produce an enclosure with unprecedented safety performance. This has required a completely new approach, beyond anything in the market. The resulting dynamic, elastic net system more than meets the main objectives of the standards, and some revision of the standards may result from its introduction.

Small Trampolines and Enclosures

The injury statistics show that in many places the greater number of injuries occur to children in the five- to ten-year-old age group. Sixty-two percent of all injuries were to five- to nine-year-olds in Nixon's study quoted above. Frequently these young children are using smaller trampolines, which may seem to parents to be more appropriate and more cost-effective for smaller children.

Unfortunately smaller trampolines give less room for error when negotiating landings. Also they are only rarely, if ever, able to be supplied with an enclosure. (The writer was unable to identify any suppliers shipping smaller trampolines with enclosure net systems.) One of the difficulties with mounting an enclosure on these small trampolines is that it makes them vulnerable to being tipped over when a jumper hits the barrier. This is because the smaller trampoline is inevitably lighter and has a narrower leg spread.

Aware of these safety and performance issues, SpringFree has addressed the problem with its specially designed smaller unit, the SpringFree SF40E, shown in part in Figure 18. Its features are:

- It is small, just over 8' in diameter (in contrast to the 12' SF90E).
- Its low mat stiffness is much more suited to smaller children, but it is still usable for adults (Static load tested to 380 g)
- The edge is softer than that of the SF90E.
- It is specially suited to small yards given the mat size at 8' 3".
- The enclosure system uses the SpringFree technologies described above.
- The trampoline has been specially engineered so it cannot be tipped over by children; it has a particularly wide leg spread (see Figure 19).
- The whole trampoline is just over half the weight of the 12' SF90E.

Figure 19: Tipping test of the SF40E with an over-the-weight-limit engineer climbing on the outside of the enclosure. Extra stability is provided by the splayed legs.

Mat Stiffness

As well as being safe, SpringFree trampolines are designed to provide a superior soft bounce.

Trampolines with shorter, stiffer springs have a jarring stop to a deep impact on the mat. By contrast trampolines with longer, softer springs have a much softer end to a deep mat impact. Doctors and trampoline coaches approve of the benefits of a softer bounce for the simple reason that it puts less load on the jumper's joints and body during exercise, play or training. This reduces the chance of joint and muscle strain injuries.

SpringFree rods are designed to be equivalent in stiffness to 10-inch gymnastic trampoline springs (low stiffness at 680 N/m). These are the softest and longest that are commercially available. By contrast most domestic trampolines are fitted with a completely different design of spring, smaller in diameter and only 7 or 8 inches long (high stiffness at 2950 and 2050 N/m respectively). These springs result in

a much harsher bounce. This means the SpringFree bounce is softer than virtually all other recreational trampolines on the market.

To illustrate, the effect of the springs and spring stiffness is shown by calculation in Figure 20, where the load on the jumper's legs is plotted against how far the mat deflects during impact. The higher the jumper jumps, the greater will be the mat deflection on impact. Normally a 75 kg amateur jumper can jump about 1.5 m into the air and produce about 500 mm mat deflection.

It can be seen in the figure that on the SpringFree trampoline (lowest line) the leg load is about 160kg at 500mm mat deflection (lower yellow dot). That is about twice the jumper's weight.

If the rods were to be replaced with USA STD 8-inch springs (found on most US domestic trampolines) the leg load calculated would be about 280 kg (upper yellow dot) for the same mat deflection. This is nearly 4 times the jumper's weight. The effect for the jumper is that the USA STD 8-inch springs produce a relatively abrupt jarring stop at the bottom of the bounce. A secondary effect is the jumper will not be prepared to jump so high because the loads on landing are uncomfortably high at 280kg.

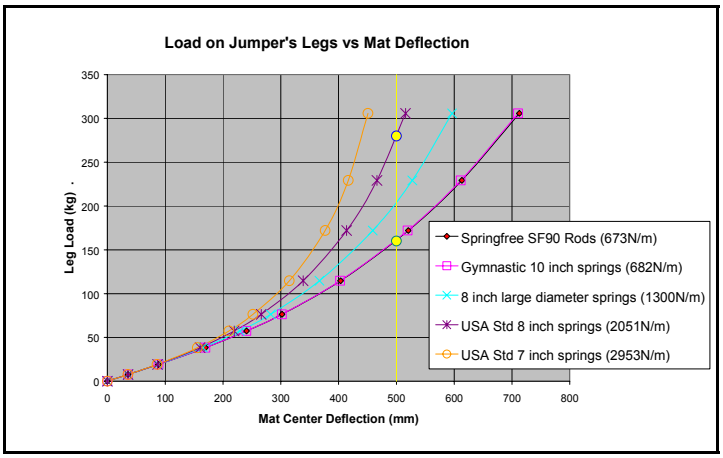

Figure 20: The calculated effect of different springs on the same trampoline (Same number of springs; all springs start at the same preload in each case; The SpringFree curve sits right on top of the Gymnastic curve)

So the SpringFree trampoline is not only safer and gentler, but also provides more opportunity for challenge.

SpringFree Trampolines and the Safety Standards

The evolving trampoline standards represent the knowledge and experience of generations of interest groups. And they represent current best practice and safe practice. The SpringFree engineers have used the existing standards of several countries as a guide while designing and consumer testing their product. They have come to

understand the reasoning behind the guidelines, and where possible they have endeavoured to exceed them.

In some cases, particularly to do with safety they have been able to demonstrate very significant improvements over standard requirements. Since the compliance requirement is an ongoing and evolving task in our modern societies, SpringFree representatives are involving themselves, where appropriate, in representation on standards committees.

Appendix 1 lists the standards, compliance issues and tests carried out on the SpringFree trampolines.

Conclusion

A trampoline presents a stimulating environment that encourages skill development, provides manageable challenges, and enables children to delight in finding and testing their physical limits.

It provides opportunities for the development of motor skills, exercise and fitness, increases kinesthetic intelligence[3] and presents a healthy, real-world alternative to more passive pursuits like *X-Box* and television.

The major risk has always been the potential for injury from the trampoline structure itself. The SpringFree engineering strategy has been to start with a clean slate and come up with a trampoline system ideally suited to the challenging tasks that children set themselves, while delivering unprecedented levels of safety.

Eleven years of world class engineering and product development have removed all the traditional hazards of conventional trampolines and delivered to the market a paradigm improvement in one of the most popular pieces of play equipment that children experience.

[3] For more information on the kinesthetic benefits of trampoline use, see our related whitepaper, "Bodily-Kinesthetic Intelligence: Trampolines—Recreational or Developmental Tool"

Appendix 1: Compliance List

The SpringFree team acknowledge the authority and experience embedded in the standards and while compliance is not necessarily compulsory, they have made every effort in the design to not only comply with the letter, but to understand and comply with the spirit of the relevant standards.

Standards that SpringFree Trampolines Have Been Designed to Comply With

- American Standard ASTM F381 – 01: "Standard Safety Specification for Components, Assembly, Use, and Labeling of Consumer Trampolines" (2001)
- American Standard ASTM F2225 – 03: "Standard Safety Specification for Consumer Trampoline Enclosures" (2003)
- Australian Standard AS NZS 4989-2003 "Trampolines"
- BS EN 13219-2001. "Gymnastic Equipment—Trampolines—Functional and Safety Requirements, Test Methods"

Standards Compliance Tests Undertaken by Independent Laboratories

- Powder coated frame samples were subject to accelerated neutral salt spray conditions for over 1500 hours, in accordance with AS3715: 1989 to confirm corrosion performance. (Ameron Coatings laboratories)
- Trampoline edge tests to ASTM F381 using procedures in ASTM F355 to confirm Severity Index. Maximum value for compliance, SI=450. Value measured for SpringFree SF90E trampoline: SI = 13
- Trampoline edge tests to AS 4989 2003 using procedures in AS/NZS 4422 1996 to confirm critical fall heights. (That is, the height of a fall on to the mat edge that will cause a critical head injury). Minimum value for compliance with the standard: 1.5 m. Value measured for SpringFree SF90E trampoline: 4.6 m to 6.2 m.
- Trampoline edge tests to AS 4989 2003 using procedures in AS/NZS 4422 1996 to confirm G_{max} values. Maximum value for compliance, G_{max}=200. Value measured for SpringFree SF90E trampoline: G_{max} = 80
- Tests of lead and heavy metals content in powder coating have been undertaken to comply with CHPA R.S., Schedule I, Part I, Item 9: Heavy metals content: requirement for total lead content of no greater than 0.5%, soluble heavy metals (antimony, arsenic, cadmium, selenium, barium) PC 6572 California Prop 65.
- Extreme Temperature tests: 24 hrs at -32F and +140F. No failure
- Short-term UV tests Class 4.0 at 40 hours and class 3.0 at 100 hours have been conducted. These test up to five materials/colors that have the highest potential for fading or largest surface area.

Standards Compliance Tests Undertaken by SpringFree

- Static load tests have been conducted using the procedures of BS EN 13219-2001. That is, the SF40E has been static load tested to 380 kg (830 lb) and the static load test for the SF90E is 490 kg (1070 lb), with a mat deflection of less than 80% of mat normal height, and no damage to any components.
- Enclosure Impact tests to ASTM F2225 Section 6.1.1. This requires a test load of 90 kg hung on a 3m rope, to be swung from 30° into the enclosure net, rods or door with no damage. The SpringFree enclosure easily complies with this test.