Springfree White Paper Update

Draft 9

Keith Alexander 22/3/21

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1.0 Origin and Purpose

Ideally, a trampoline should provide a stimulating environment which presents children with manageable challenges, through which they can find and test their limits, and develop their gross motor skills. In providing these challenges, a trampoline must achieve a careful balance between risk and safety. Parents understand their children need to take risks to develop, but they will also require that the consequences be kept within a range of normal childhood mishaps (Figure 1).

In industrial safety, there is a recognized hierarchy of hazard control measures, starting with the principle that hazards should be 'engineering out' if at all possible, and ending with the idea that personal protective equipment is a last line of defence.

Figure 1: Children will naturally seek out challenges to find and test their limits.

From the trampoline designer's perspective the ideal approach is to re-think the concept from the ground up, engineering out unacceptable hazards by inventing new and better ways to deliver the aspects that children love, while at the same time, incorporating features that avoid the hazards and limit the consequences of misjudgement and over-enthusiastic behaviour.

An ongoing analysis of worldwide trampoline injury data initiated in 1994 by Keith Alexander revealed that in order to build a safer trampoline three major impact zones would need to be engineered out of the traditional design:

- The steel frame, unforgiving and dangerously close to the jumping surface
- The springs, and the gaps between them, also close to where the children were jumping
- The ground and obstructions on the ground, which could be hit as a result of children falling off the trampoline altogether

After 11 years of engineering design, materials innovation, prototyping, and the application of significant international venture capital, a new trampoline technology was brought to the market, with these three major hazards designed out.

2.0 What are standards?

A standard is a set of rules on how to make something or do something. They are made to get safety or consistency in products. They are produced by people interested in the particular product, such as manufacturers and consumer advocates. To ensure fairness, the group of people is usually a balanced mixture of customers, manufacturers and experts. Countries have a standards organization that administers the development and maintenance of standards.

Trampoline standards are concerned primarily with safety. They outline tests that trampolines must pass to ensure they are safe for children to use.

Standards can be mandatory and you must obey them by law, or voluntary, and you can choose to follow them or not.

Currently trampoline standards are voluntary. This means manufacturers can choose whether or not to comply with them. This leaves it up to the customer to decide whether or not to buy a trampoline that does not comply with the standards.

There are 4 trampoline standards: They are similar in what they require. The standards are: USA: ASTM F381 and F2225. Australia: AS4989, and Europe: EN 71-14. Manufacturers will state what standards they comply with, and it is illegal for them to falsely claim compliance.

Springfree aims to exceed the requirements of all 4 standards, and has contributed to the development of all of them.

In some countries consumer advocate agencies periodically test trampolines to see whether they comply with the standards for that country. This is useful for customers and can be a good guide as to whether trampolines actually comply with the standards or not.

3.0 The Edge

There are a number of design issues with the edges of traditional trampolines. Because they are designed with a frame and springs around the edge of the jumping surface, the safety goals are 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

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

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-absorbing material to prevent injury from falling on the frame or 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.

These solutions have had limited success because:

- Padding material is costly so the minimum thickness of padding is used – frequently less than will meet the standards.
- 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 foam chosen for padding can be inferior and 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 last a reasonable time in the outdoor environment.
- To provide protection for the life of the trampoline, maintenance must happen. Research evidence is that pads that fail are rarely replaced.

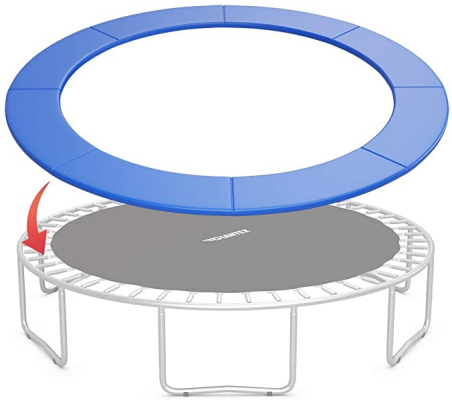

Figure 4: Unless anchored adequately, padding will move and will not prevent impacts with the frame.

3.1 Soft Edge Trampoline Concepts

To get around these issues, 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 (examples in Figure 5 and Figure 6), and one chosen for further commercial development.

Figure 5: The first unit built for customer trials.

Ultimately the rod-type trampoline of Figure 7 was believed to provide the best mix of characteristics (Ref 1). After systematic investigations of five rod material options, a pultruded, glass fibre, composite was chosen as the most promising for strength,

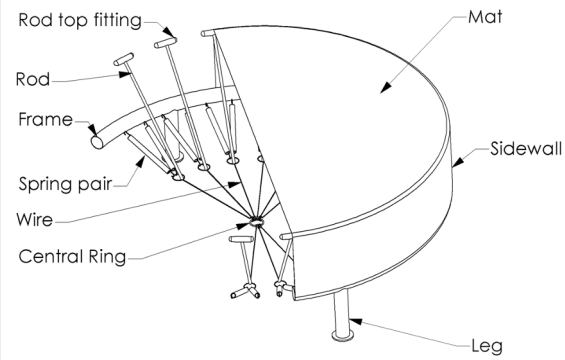

Figure 6: Second Concept, built for trials and commercial assessment

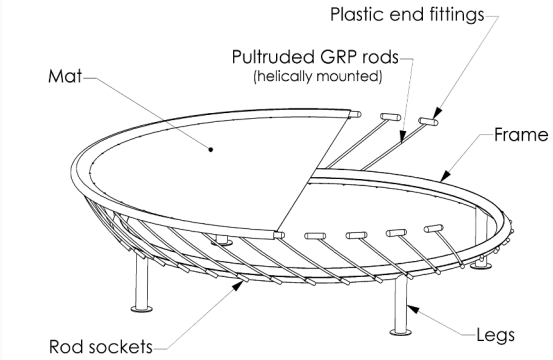

Figure 7: Schematic of the final concept model built for trials and commercial assessment

weight and cost. Materials scientists have since enhanced the properties further so that now Springfree uses a proprietary high performance composite design, tailor-made for this application. The final result is a consistent, non-corroding, long-lasting, trouble-free, resilient suspension system.

3.2 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 and Figure 10. To connect with the mat, the ends of the rods have to be bent inwards towards the centre. The force needed to bend them inwards is the force that keeps tension in the mat (Figure 8 and Figure 9), so the mat is tensioned just like the mat of any other trampoline.

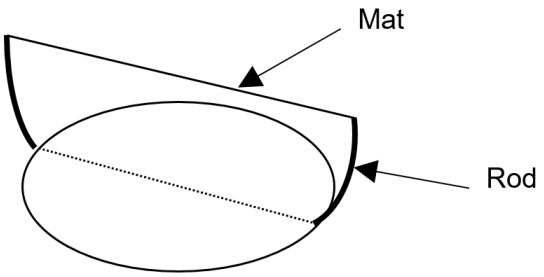

Figure 8: Bend pultruded rods inwards to get tension on the mat

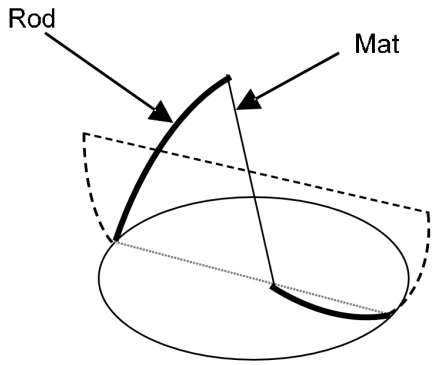

Figure 9: Lay the rods over so they will squish down if landed on

Laying the rods over as in Figure 9 can be done while still maintaining the tension between the rods. But with the rods like this, if anyone lands on the ends of them they will bend down as in Figure 18. In this way the rods provide both:

- The necessary tension in the mat and
- A flexible edge that does not need padding.

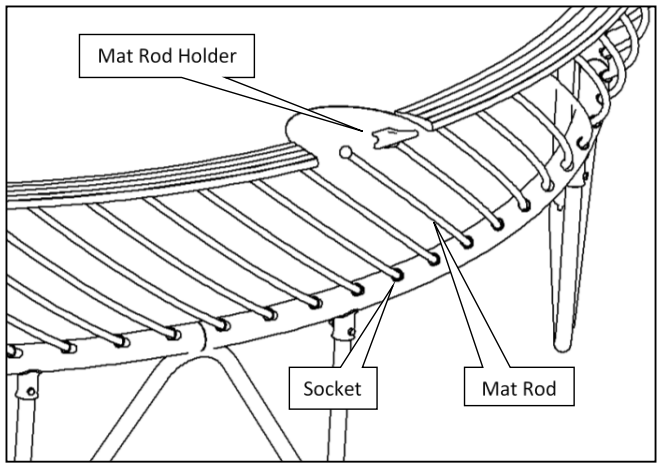

Figure 10: Cutaway showing the components of the soft edge

3.3 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 Trampoline composite must be treated properly. The matrix is a plastic and as such, is slightly susceptible to ultra-violet (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 light, fine fibres come free and these can cause irritation when exposed rods are handled.

For these reasons these rods are enclosed in UV-resistant plastic sheaths. These protect the rods from mechanical damage and UV light, as well as ensuring lifelong, trouble-free handling. The sheathing is shown in Figure 11.

Figure 11: Springfree high-tech composite rods are encased in a plastic sheath to provide mechanical and UV protection, and trouble-free handling.

3.4 Edge Connections

The connection between the rods and the mat required considerable development work and resulted in several patents. Over 10 plastic mat-rod holder designs have been built and tested in the process. The current mat-rod holder design is shown in Figure 12 to Figure 16. It has the following features:

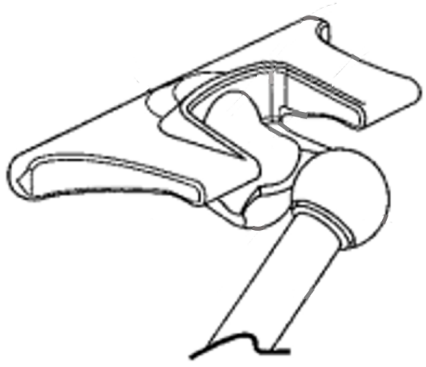

Figure 12: Mat rod holder during assembly

Figure 13: Mat rod holder viewed from below

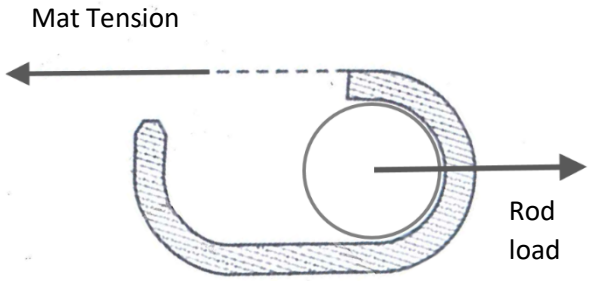

Figure 14: Schematic of mat rod holder assembled - mat tension is opposed by rod load

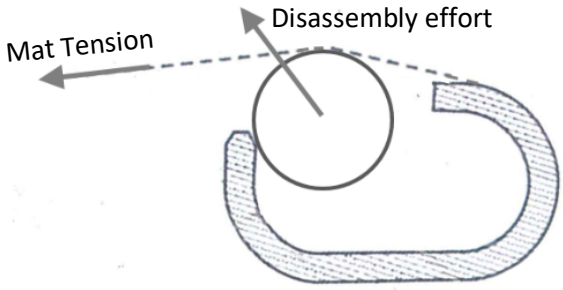

Figure 15 Disassembly effort must push up against mat tension to release rod

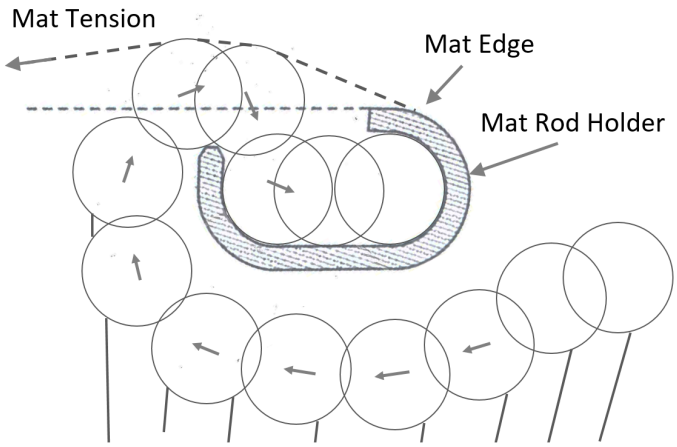

Figure 16: The assembly - disassembly path of the ball into the mat rod holder

- The mat-rod holders have a large flat top face to provide a safe landing surface at the rod end (Figure 12).
- A long loading edge to spread the load into the mat edge and reduce wear points
- Permanent connection between the rod and the ball (Pull-off force over 800lb (350kg))
- Ball and socket joint that captures the rod end but allows freedom of angular movement
- Clever design that ensures the ball cannot be released from the socket inadvertently
- Requires deliberate force up against the mat tension to release during disassembly (Figure 15 and 16).
- Made of a high stiffness, UV-resistant material, designed to outlast the mat
- They are sewn into the mat at the factory and are simply slotted on to the rods during assembly of the trampoline in the customer's back yard.

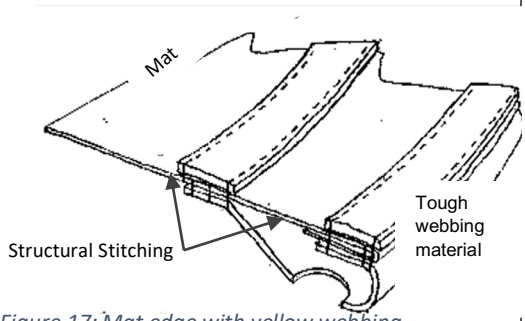

Figure 17: Mat edge with yellow webbing protecting the structural stitch lines

The current mat edge design is shown in Figure 10 and Figure 17, and has the following features:

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

3.5 Edge Landings

The Springfree trampoline is designed for people to land safely on the edge. By design, the rods are laid over at about 30 degrees (see Figure 9) so if someone lands heavily on the edge, the rod below is deflected down, pulling its neighbours with it (Figure 18). The effect is that the edge behaves like a safe, flexible and resilient rim to the mat.

Figure 18: A heavy bounce on the edge: about 450lb (200kg) with no damage

3.6 The Squish Distance

The squish distance is the distance the edge will deflect down before it hits something hard. The Springfree trampoline has the greatest squish distance in the industry as shown in Figure 19. The effect is most graphically demonstrated in Figure 18.

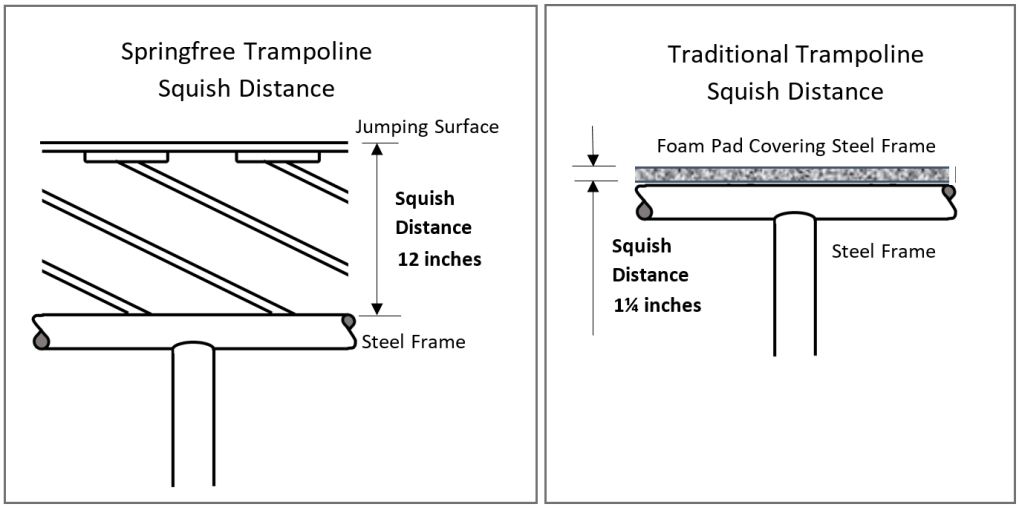

Figure 19: The Springfree Squish Distance is the largest in the industry providing exceptional protection against impact injuries on the trampoline edge.

3.7 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 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 20 and a brief calculation will show why this is:

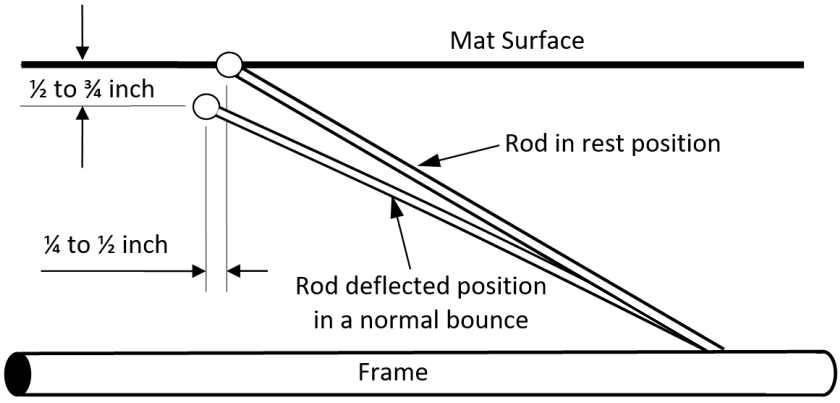

Figure 20: In a normal bounce, the mat edge moves circumferentially about ¼ to ½ inches (5 to 10 mm).

During a normal bounce the mat edge moves primarily in and out radially from the mat centre, by about 1 to 2 inches (25 to 50mm). It also moves up and down by about ½ to ¾ inch (12 to 20mm). 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 20) by ¼ to ½ an inch (6-12mm) as shown. This means the edge moves around about one sixth to one-third of a degree. To put this in perspective, if a (round) 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.) This is shown to scale in Figure 21.

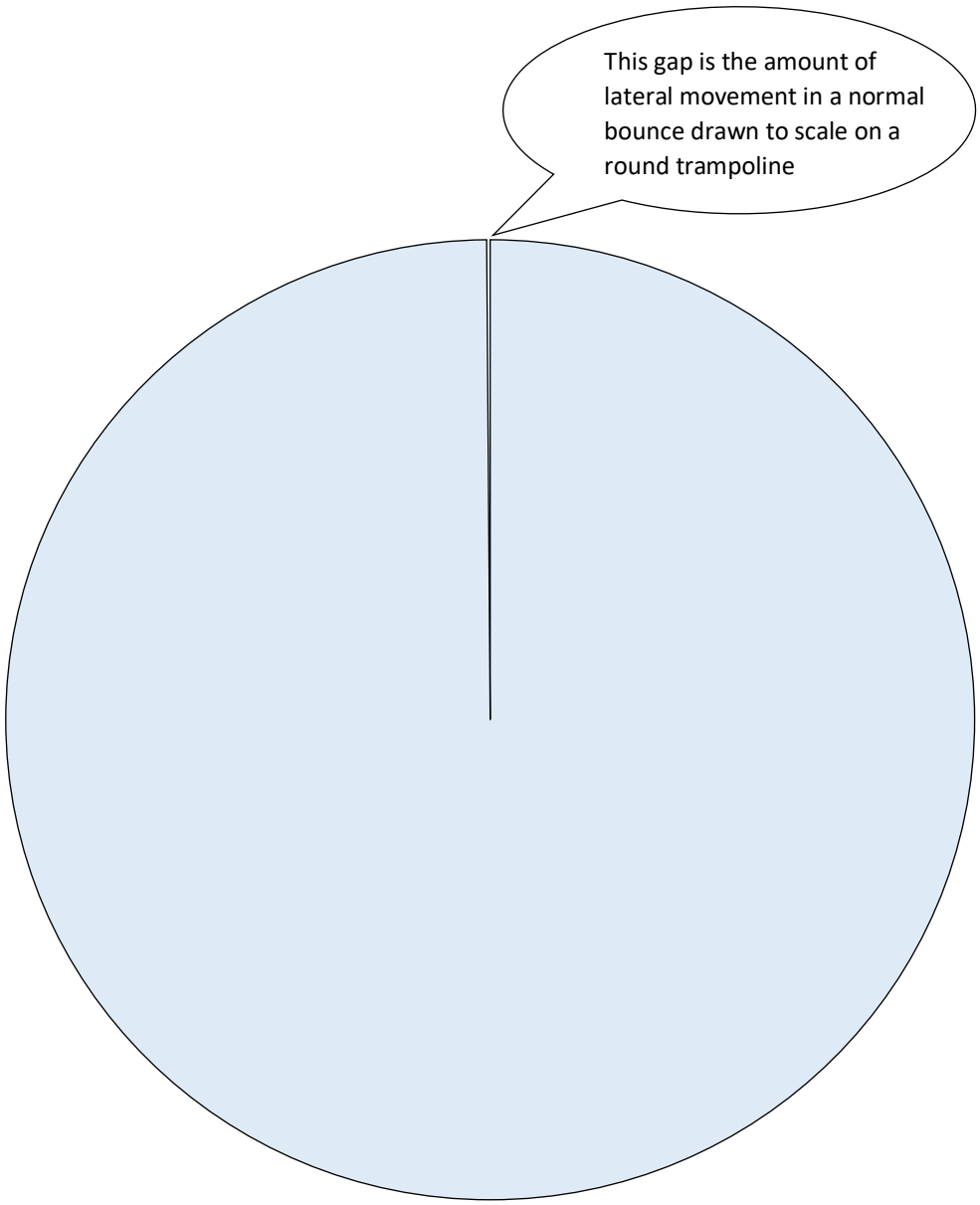

Figure 21: The mat twist in a normal bounce with the jumper in the center of a round trampoline

In other words, the lateral motion is all but undetectable, especially when bouncing. So in practice, with the enclosure in place the lateral movement is simply not registered by the jumper.

4.0 Mat Stiffness: How the Bounce Feels

- Traditional trampolines with short, stiff springs have a jarring stop to a deep impact on the mat. By contrast Springfree trampolines are designed to provide a relatively soft deep bounce.
- Springfree Trampoline rods are designed to be equivalent in stiffness to the long 10-inch trampoline springs (low stiffness at 1160 N/m) while many domestic trampolines are fitted with

springs that are small in diameter and 6 to 8 inches long with three times the stiffness (up to 3700 N/m).

- Doctors and trampoline coaches approve of the benefits of a softer bounce because it puts less load on the jumper's joints and body during exercise or play, for adults as well as children. This reduces the chance of joint and muscle strain injuries.
- The effect of the springs is illustrated in Figure 22 where the load on the jumper's legs is plotted against how far the mat deflects for different springs
- The higher the jumper jumps, the greater will be the mat deflection on impact. Normally a 150lb (70kg) amateur jumper can jump about 4ft (1.2m) into the air with a mat deflection of 20 inches (500mm).
- Figure 22 has yellow dots to illustrate the difference between the force on the feet of a jumper that is either jumping on the Springfree Large Square (lowest dot) or a traditional "10ft" trampoline with 6 inch springs. The load is nearly twice as high on the traditional trampoline for the same mat deflection.
- The jumper will not be prepared to jump so much because the loads on landing are too high.

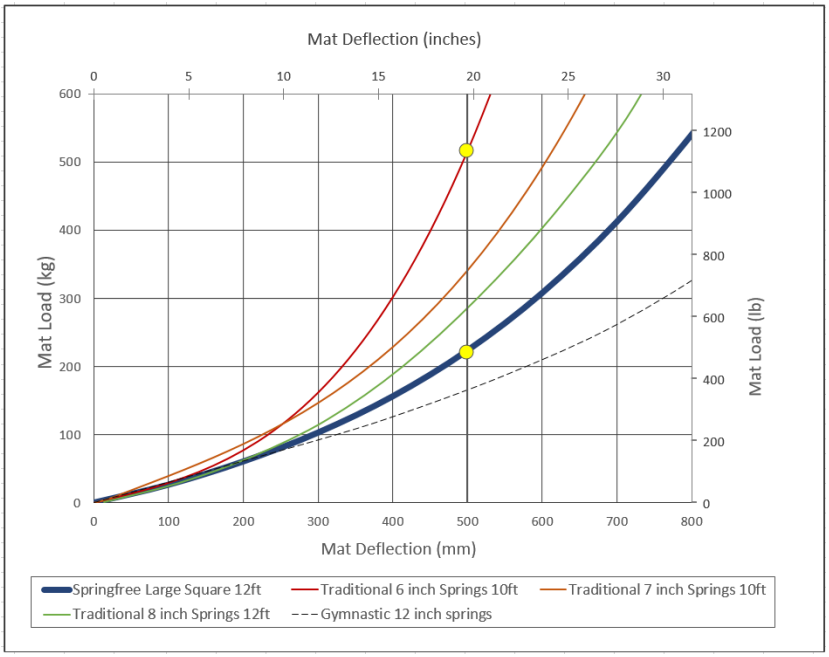

Figure 22: For different trampolines, a bounce depth of 20 inches (500mm) creates a force on the jumpers feet is anywhere between 350 and 1150lb (160 – 510kg). Springfree trampolines are at the lower end of the scale.

4.1 Finding the force deflection curve

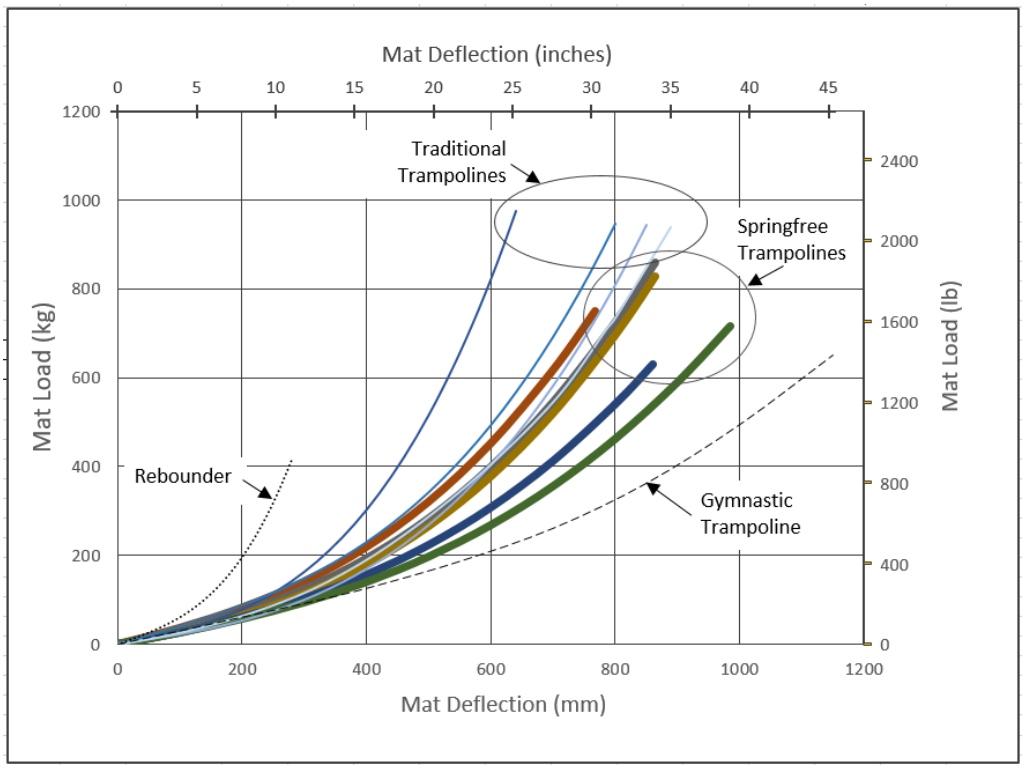

Figure 23: Force deflection curves for some of the Springfree trampoline models

- Springfree tests all its models to verify the force-deflection curves, maximum user weight and static load limit.
- Typical results are shown in Figure 23.
- The process uses setups like those later in Figure 28 and Figure 29 shown later.

4.2 What is Bouncy?

People have different ideas for how they judge that a trampoline as more or less bouncy. The different characteristics that people use to judge seem to be:

- How firm the mat is – how little it deflects when you walk on it: Some people judge it as more bouncy because it feels firm to walk on.
- The soft deep bounce (the lower lines in Figure 22). The steady increase of force on the feet as the mat is deflected is believed by some to mean it is more bouncy.
- The harsher response: The upper lines in Figure 22. The sudden increase of force on the feet as the mat is deflected is believed to show more bounce.
- The trampoline shape: Rectangular trampolines are sometimes said to be more bouncy.
- The jump height that can be achieved for the least amount of effort.

From the technical perspective the last point is the one that is considered for the design of trampolines. The central idea for this is: Bounciness is the amount of energy that the trampoline gives back to the jumper on each bounce. The more this is, the higher the jumper will go after a few bounces.

This can be measured in a drop test where the rebound height is compared with the initial drop height. This gives the “Coefficient of Restitution”. Springfree has done these measurements for its trampolines and the results are published in an academic paper (Ref 2). One setup for this test is shown in Figure 24, where a 132lb (60kg), test ball is suspended at a drop height of 5ft (1.5m) above the mat. The rebound in this case will be about 68% of the drop height, or 3.4ft (1m).

Figure 24: Test setup for measuring coefficient of restitution

The results of research on drop tests like this show that:

- Most of the wasted energy is lost by air-pumping, caused by the trampoline mat motion
- Smaller mats therefore lose less energy
- More porous mats also lose less energy, because the air can pass through them to some degree
- Gymnastic trampoline mats are much more porous than back yard trampoline mat material, and therefore the jumpers can get much more height on gymnastic trampolines
- Springfree bounciness by this measure, is virtually identical size-for-size with spring-based trampolines
- The controlling feature for this measure is mat the area (See Figure 25).

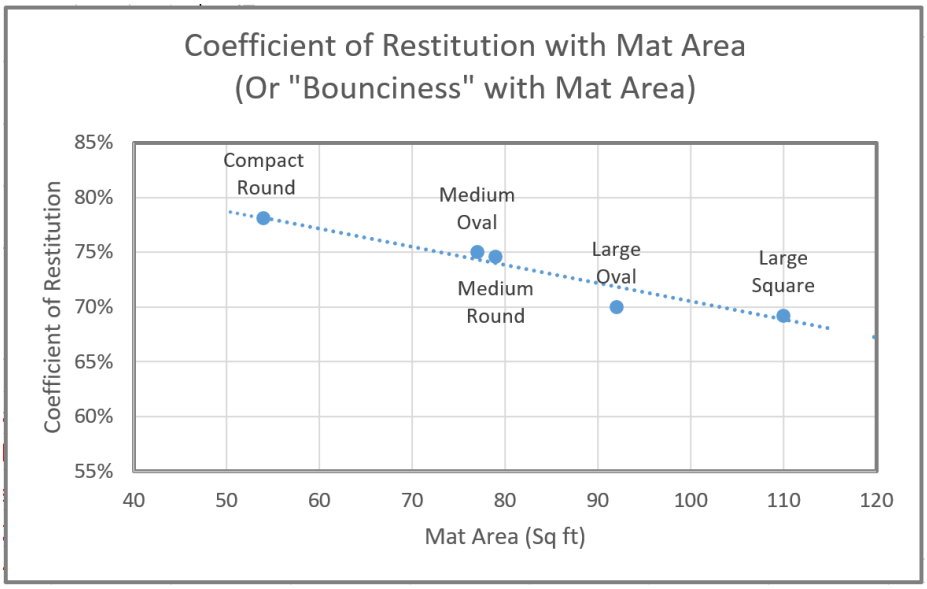

Figure 25: A technical measure of bounciness for a range of Springfree trampolines

- A question that is sometimes asked is: Why not have a very porous mat like the gymnastic trampoline mat, for back yard trampolines?
- The answer has to do with safety: We don't want children bouncing too high. It is safest to keep the bounciness at the current level for domestic trampolines, with the long-lasting mat material that we have had in the industry for many years.
- For people who want greater jump heights it is strongly recommended that they join gymnastic trampoline clubs that are well set up to guide safe trampolining at greater jump heights.

5.0 Maximum User Weight, and Static Load Rating

5.1 Maximum User Weight

A person of the maximum user weight should be able to do a seat drop from 1.5m (5ft) above the mat, without hitting the ground and breaking a tailbone, (a surprisingly debilitating injury), see Figure 26. The standards specify that this is the case.

The maximum user weight is controlled by this rule in the standards, the firmness of the mat, and its height from the ground. This will vary between different manufacturers and trampoline models. **The standards require the manufacturer to specify the maximum user weight based on this rule and on load test results**. The maximum user weight is also used by the standards to define the strength of the frame and the strength of the enclosure net.

Generally speaking a softer the mat will feel, the better it is for smaller children - but it will have a lower safe user weight. And conversely: a firmer mat will feel better for bigger people and will have a higher safe user weight.

A person above the maximum user weight can safely be on the trampoline, but they need to be aware that the trampoline is designed for the safety of smaller people, so they should use it with caution and avoid doing seat drops. The trampoline will certainly not break with a person of the maximum user weight, but their safety margin is below that required by the standard.

The trampoline maximum user weight is very different than the **static load rating**, which is the load that could break the trampoline itself as discussed next.

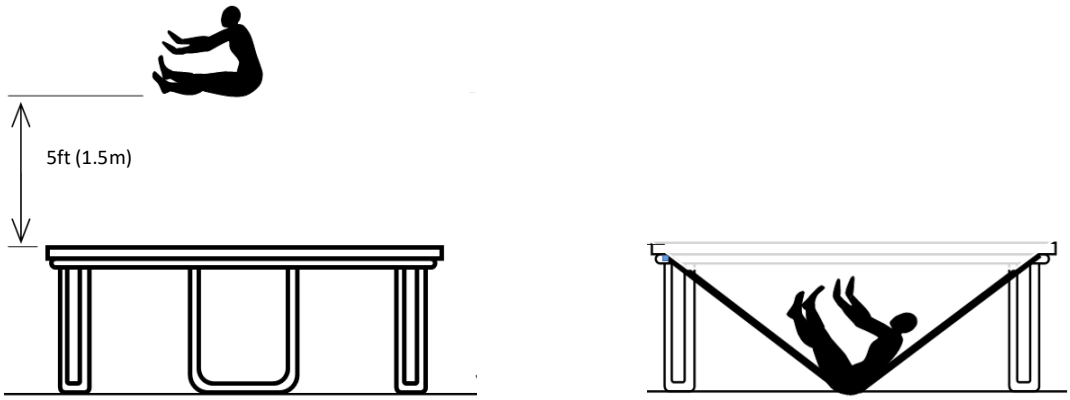

Figure 26: The safety concern that defines Maximum User Weight

Note: The European standard allows a much greater maximum user weight than the American and Australian standards but the Springfree trampolines are built to comply with the most stringent case. Ref 3.

5.2 Static Load Rating

The Static Load Rating is the maximum load that can be on the trampoline before there is risk of it breaking. The Springfree trampoline, because of its unique suspension system, has to be designed much stronger than traditional trampolines and consequently has a greater static load rating.

There are two possibly ways a static load can be applied:

1. Load in the centre of the mat

In normal use the maximum load on the mat is when it is deflected right to the ground. This load is about 1550lb (700kg). Springfree tests this load case on all its trampolines (Figure 27).

A particularly athletic teenager can generate this type of load when jumping, consequently all Springfree trampolines are built to sustain this load safely and without damage.

Figure 27 and 28 show the procedures used to measure this mat-centre, static load capability, and to form the force-deflection curves in Figure 23.

2. Load around the edge and on the frame

In this case the load is at the edges of the trampoline, which on a traditional trampoline will be on the frame or pads. On the Springfree trampolines this will be right on the edge of the mat.

The suspension system of Springfree trampolines can deflect almost down to the frame without damage. An example is shown in Figure 18, where the jumper has deliberately landed heavily on the edge. At this much deflection the load on the jumper's feet is about 440lb (200kg). If the rods were deflected down like this all the way around the edge (for example, by 20 people shoulder to

shoulder around the edge), the total load would be about 1.5 ton, and as shown in Figure 18, the suspension system can carry that load.

Now considering the Springfree frames: any single frame section between the legs can carry over 880lb (400kg) and there are at least 4 of those per trampoline. Further, each leg centre post can carry over one tonne and there are at least 4 of those.

So in summary the static load capability of the frame and suspension system of a Springfree trampoline is over 1.5 tonne

Figure 29 shows an accidental load test by an SUV which dropped from a low wall on to the trampoline when its handbrake failed to hold it on a slope. There is no visible damage to the trampoline frame, and the suspension system is shown carrying most of its weight. The vehicle has a curb weight specification of 2 tonne.

Figure 27: Crane undertaking static load testing with 1 tonne of water and a load cell below the hook.

Figure 29: Nissan Xterra SUV, accidental trampolinist. Curb weight of 2 tonne

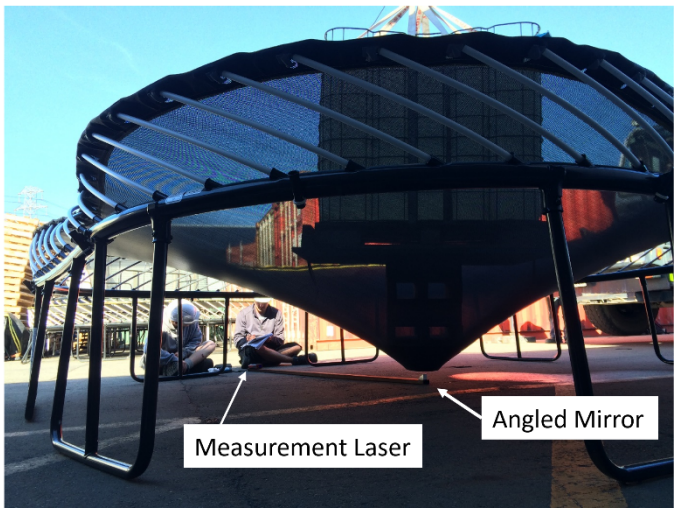

Figure 28: Engineers measuring loads just before ground contact. This is how the force-deflection curves are determined.

6.0 Enclosures

6.1 Enclosures on Traditional Trampolines

The most serious injuries in the US data as reported in research papers (Ref 4) were from children falling off trampolines and on to the ground, or on to obstructions on the ground.

The enclosure is a netting barrier structure intended to prevent children from falling off. Typical traditional enclosure nets are shown in Figure 30 to Figure 32.

Figure 30: Traditional trampoline with enclosure net supported by padded steel poles

Figure 31: Action shot: On a conventional trampoline the net catches the jumper and guides him down to impact on the steel frame, which is often not adequately padded.

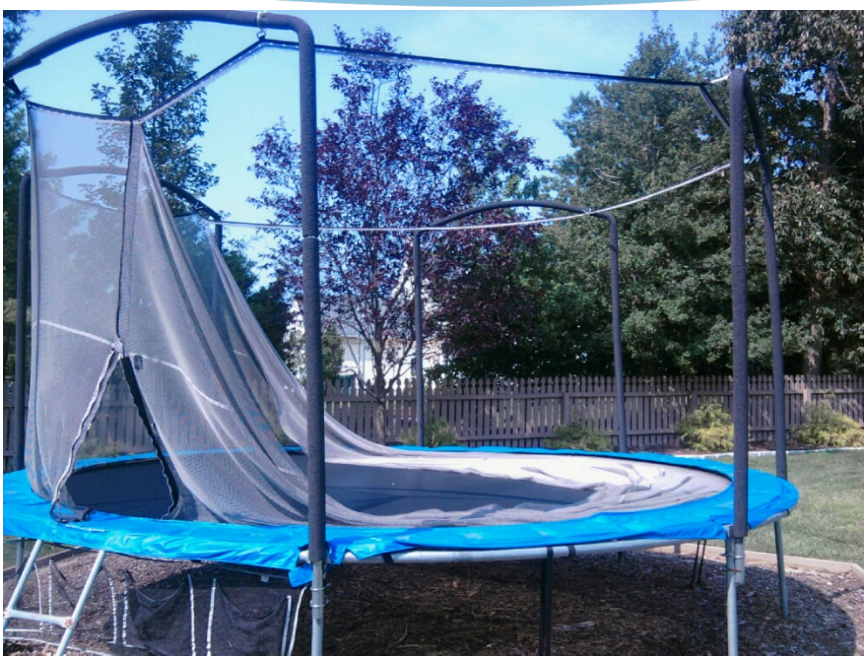

Figure 32: Common deterioration: the net fails from UV exposure and the padding comes off the poles

6.2 Falling-Off Injury Statistics on Traditional Trampolines

For many years about 25% of trampoline injuries were from children falling off because there was no net, or the net had failed (See Figure 32). Even now that nets are compulsory, 20% of backyard trampoline injuries are from children falling off (Ref 5).

6.3 Risks from Enclosures on Traditional Trampolines

Conventional enclosures, as shown in the three figures above, unfortunately introduce several new risks:

- The net itself, or the net attachment components often deteriorate over time so that the net ceases to work effectively (as in Figure 32)
- The jumper may hit the net and then be guided down, only to fall on to the steel frame below (See Figure 31). This can occur whether the net is inside the safety pads (as in Figure 30) or outside the frame as in Figure 32).
- The net attachment may not be applied correctly by the customer (some net attachment procedures are quite complicated).
- The jumper may hit the steel pole that supports the net (the padding cover often deteriorates)
- The jumper may come down on to the top of a pole.

6.4 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 aim:

- To ensure the net system is large and strong enough to perform its function without deterioration (unlike the net and poles in Figure 32)
- To require adequate flexibility, or to put padding on poles - to prevent injury from impacts
- To require adequate flexibility, or to put suitable buffers on the tops of poles to prevent impalement
- To avoid sharp points, loose cords or entrapment risks

7.0 The Springfree Trampoline Enclosure System

The target for the engineers at Springfree was to produce an enclosure with unprecedented safety performance. This has required a completely new approach, a paradigm shift beyond anything in the market. The resulting dynamic, elastic net system more than met the main objectives of the standards. The Springfree Trampoline enclosure, as shown in Figure 33 to Figure 37.

Figure 33: The Springfree net system

Figure 34: Enclosure rods are strong enough for extreme misuse.

Figure 35: The Net - a new play surface

The Springfree net was not designed as an afterthought or Band-Aid, but as an integral part of the whole concept. Like the mat edge, it provides a soft and safe surface for all impacts. With this in mind it has the following features:

- While it fully complies with the standards, it is also another play surface, with adequate softness and rebound for adventurous activity.
- Any falls into the net only land the jumper on the soft mat edge (shown in Figure 18 or 35), or lower them to the ground (Figure 34), rather than land on the steel frame (Figure 31 or 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 34).
- 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 resilient structure strong enough to cushion the heaviest jumper.
- Because the rods are bowed on installation, the ball-ended upper tip is safely flexible should a jumper come down on it; any vertical load above 20lb (10kg) will cause it to buckle away.
- The soft net, tensioned by the rods, has a small, “no-climb” mesh so most 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 zippered, is easy to understand, to enter, and close. It can be padlocked to control who uses it.
- The trampoline and enclosure net are sold together, and are designed to be assembled together. This means the safety feature is in place from the outset.
- The rip-stop net material is UV protected so that its outdoor life is frequently over 10 years.
- The net pole connection pocket also has a safety strap that prevents accidental release and draws attention if the pole has not been assembled correctly (Figure 37)

Figure 36: Mother helps daughter through the zippered door.

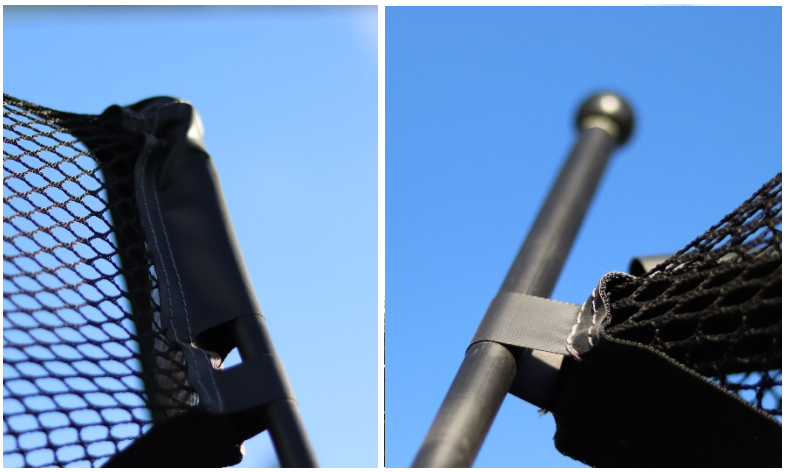

Figure 37: Net pole connection, and catch-strap (right) if it gets pulled loose

7.1 Small Trampolines and Enclosures

One of the difficulties with mounting an enclosure on these small trampolines is that it makes them vulnerable to being tipped over if a heavy jumper hits the barrier.

Aware of these safety and performance issues, Springfree has addressed the problem with its specially designed smaller units. The Medium Round model is shown in Figure 38 and its features are:

Figure 38: Tipping test on an 8ft Springree with an over-the-weight-limit engineer climbing on the outside of the enclosure. Extra stability is provided by the splayed legs.

- It is much more suited to smaller children, but it is still usable for adults (Mat Center Static load tested to 1150lb (520kg)
- It is especially suited to small yards given the mat size at 8' 3" in diameter.
- 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 as shown in Figure 38).

8.0 Longevity of the Product and its Safety Features

- Springfree's philosophy in the design of a safe trampoline has been that the safety features should last at least as long as the trampoline itself. (For a new car it would be unacceptable for the seatbelts to stop working before the car was finally off the road).
- The soft edge design of the Springfree trampolines means that as long as the trampoline works the edge remains resilient, ensuring safe landings for the life of the trampoline.
- The fiberglass rods have an outdoor life of over 10 years, as well as a 3 million load-cycle life.
- The mat material used in the Springfree trampolines has a 5000 hour UV test (required by the standards) which will typically result in 15 year outdoor life.
- In many trampolines the thread is the first point of failure both for the mat, net and pad connections. In the Springfree trampoline the fabrics, and thread used to make the net connection points, pass a 1000 hour UV test to ensure they last well.
- The thread used for the structural stitching at the mat edges is physically protected from wear and UV exposure by the overlying, colored webbing bands.
- The Springfree enclosure net itself is made from material that has passed a 1000 hour UV test and is able to survive for over 10 years in the outdoor environment.
- All fabrics and other materials are carefully selected to ensure they last well in the outdoor environment.
- The net poles are made of the same material as the mat rods, and have same 10-year outdoor life.
- Evidence that these efforts to ensure a long-life product, is reflected by the long warrantees given for the product, and the fact that there is a significant second-hand market for used Springfree trampolines.

8.1 Springfree's Own Factory in China

- Springfree is unique in the sector in having its own factory in China. It runs on lean principles and all staff are involved with the continuous improvement program. It has a very high staff retention rate. These points ensure effective quality control.
- In particular having its own factory makes it possible for Springfree to ensure critical fabrics last in the outdoor environment. This is achieved by constantly testing fabric suppliers' offerings with in-house testing facilities, backed up by tests in western labs, before permitting the materials to be incorporated into the product
- There are two engineering teams, one in China, with oversight of the production process and the other in the west, with oversight of the product design. These two teams are in daily contact.
- The factory is regularly inspected by social responsibility advocates.

8.2 Quality Assurance Test Facilities and Equipment

- Springfree has several multi-million cycle fatigue testing machines, and a policy that the basic product, and any significant changes to it, are tested for the equivalent of 10 years of backyard use by these machines.
- It has a salt spray corrosion test facility on site to test the effectiveness of the powder coating and ensure suppliers' fasteners comply with requirements
- It also has a UV test facility on site, and tests the several different threads used, as well as the webbing bands and other fabrics, such as the enclosure pockets.

9.0 Research into Injury Mitigation for Domestic Trampolines

Trampoline injuries recorded in emergency departments in the USA from 2002 to 2007 are shown in Figure below. These come from a well-cited paper (Ref 4 reviewing the on-line data from the US Consumer Product Safety Council (Ref 6). Figure 39 shows the 5 "causes" and the types of injuries that result from them.

A more recent unpublished (Ref 5) study shows a similar picture for the injuries between 2007 and 2018, with less than 7 percentage-points change for any cause, between 2007 and 2018. So things did not changed very much between 2002 and 2018.

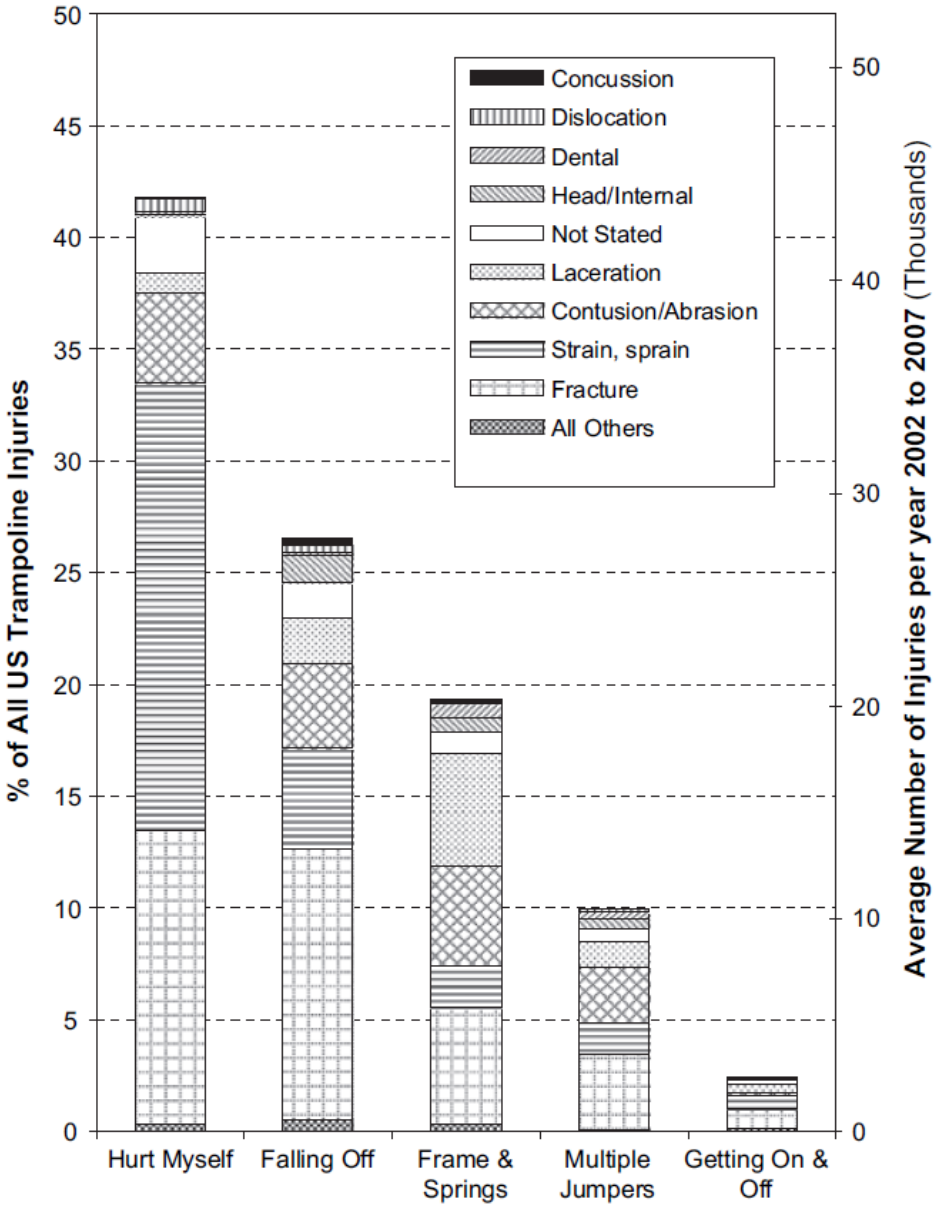

Figure 39: Analysis of NEISS data averaged from 2002 to 2007, grouped by the injury cause

These research results raise issues that are relevant to the design of safe trampolines. Standards writers are aware of them and have developed guidelines for addressing them:

- For the "Hurt Myself" and "Multiple Jumpers" causes the standards recommend warnings for the jumpers and their parents
- For the "Falling Off" causes they recommend (and now require) that manufacturers provide enclosure safety nets to stop people falling off
- For impacts in the "Frame and Springs" category, they set out specifications for impact attenuation in the padding at the edges

Issues with enclosures and "Falling Off" prevention, have already been discussed above in Section 6. Specifications for impact attenuation in the "Frame and Springs" category are now addressed below:

9.1 Impact Attenuation Specifications and the Standards

- Impact attenuation specifications in the standards, focus on limiting head injuries, because head injuries are the most critical and long-lasting injuries to children
- These impact attenuation specifications have originated from the automotive industry
- One impact attenuation measure is the “Head Injury Criterion” (HIC)
- It is widely used for helmet design and for specifying playground soft-fall characteristics
- There are tests to measure HIC and these involve dropping an instrumented crash-dummy head, on to the surface being measured, from a specified height.
- Each test results in the HIC number
- The HIC number represents the likely seriousness of an injury on impact with that surface, from that height; the higher the HIC number, the more serious the injury
- The standards give a limit to how high this HIC number is allowed to be
- Currently the maximum HIC allowed by the standards for playgrounds is HIC = 1000, and there are moves to make it lower
- While HIC is not used directly in the trampoline standards, the tests used are closely-related (Ref 7)
- Figure 40 shows HIC measurements made by students doing a University engineering research project in 2009
- It shows typical HIC values for various points on the edge of common brands of trampoline including Springfree. For the 3 traditional trampolines there are values above HIC=1000.
- Figure 40 also shows how critical these injuries are likely to be
- It is common that traditional trampolines fail this test, with HIC values greater than 1000, on the edge over the leg, as shown in the figure. This is because the padding in these areas is too thin, and making it thicker is more expensive.
- It can be seen that the Springfree results (far right) have by far the lowest HIC values and consequently the lowest risk of head injury for impacts on the edge.
- This is largely because of Springfree’s much larger squish distance that was shown in Figure 19 above.

HIC Value Comparison Chart

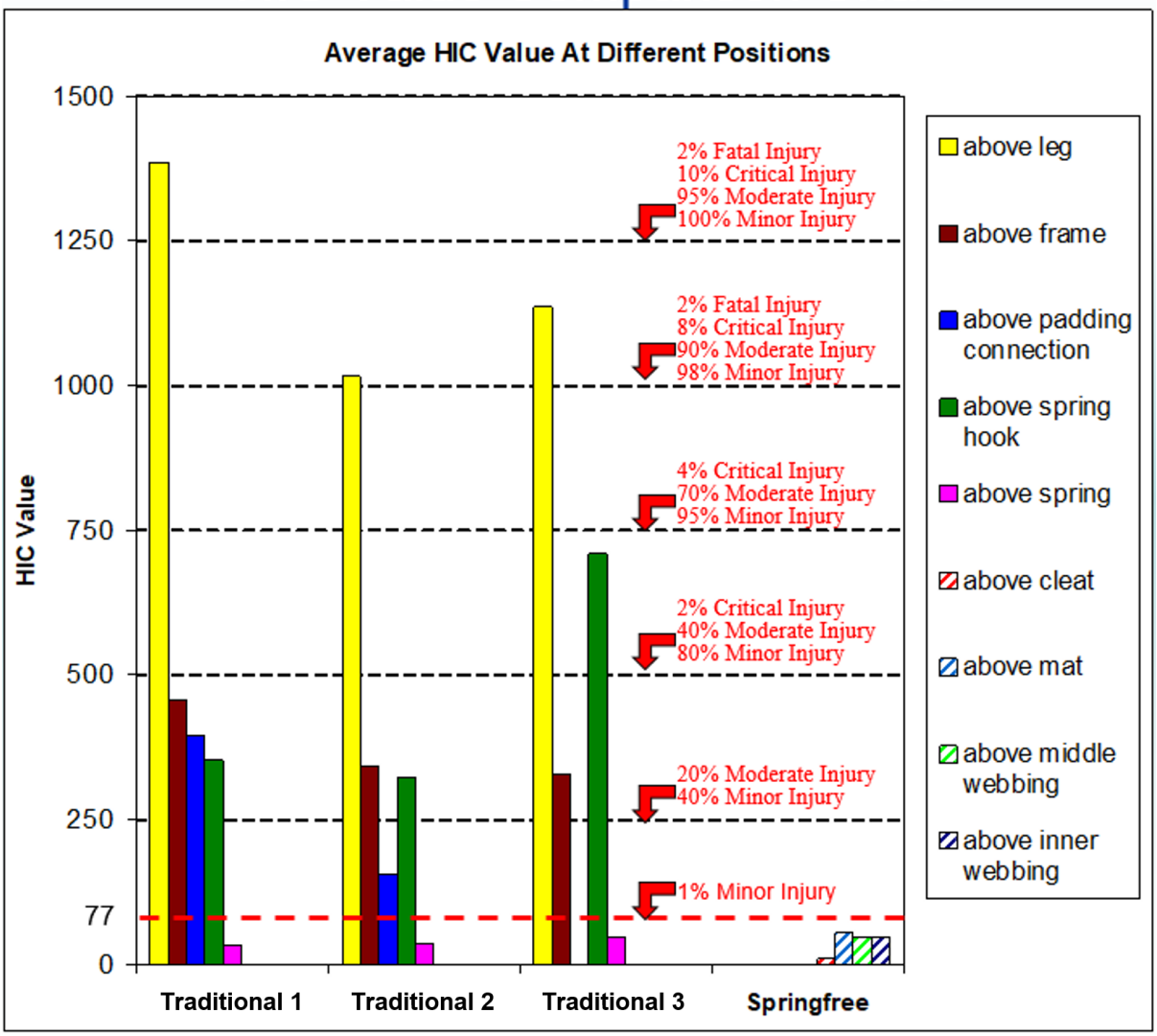

Figure 40: Test results from University of Canterbury tests showing both HIC values, and potential injury risk for 3 traditional trampoline brands when compared with Springfree in the same tests.

9.2 Research Examining the Effectiveness of the Springfree Design

- The injury "causes" in Figure 39 above can be simplified from 5 categories into 3 sectors as in Figure 41 below
- In Figure 41 the call-out labels identify:
    - Injuries that users can do something about (by heeding warnings)
    - Injuries that the manufacturer or designer can do something about …
- Figure 41 shows that over 40% of trampoline injuries in the USA are caused by things the designer can do something about.

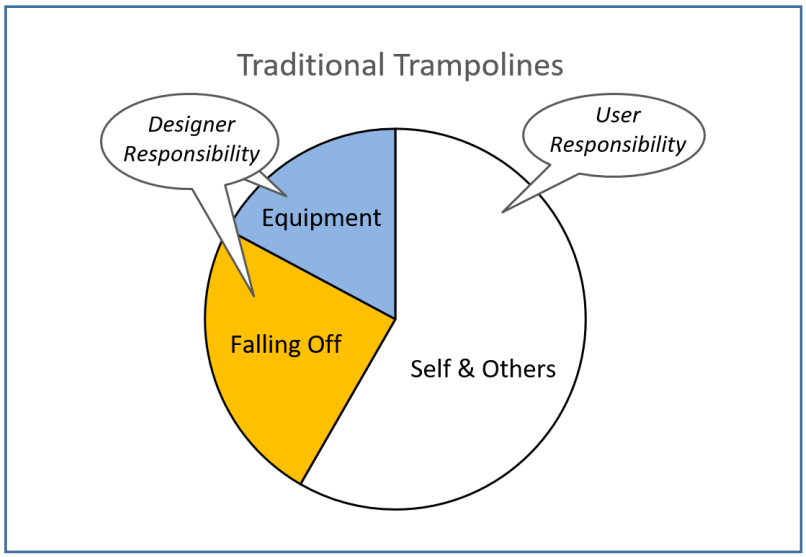

Figure 41: A simplified presentation of domestic trampoline injuries in the USA, taken from Figure 39 above

- In 2010 Springfree contributed to research that examined the injury record of its own trampolines (Ref 8)
- The results are summarised in the right hand side of Figure 42.
- These show a much reduced risk of injury from the trampoline itself or from falling off for the Springfree trampoline, when it is compared to the average US trampoline
- The "Falling Off" injuries for the Springfree trampoline were primarily because the jumpers had left the door open. Shutting the door removes 9 percentage points from what is shown in the figure.
- This information is evidence-based and comes from peer reviewed academic research journals. It was conducted in cooperation with University of Technology, Sydney
- No other manufacturer has explored and reported their injury record for domestic trampolines

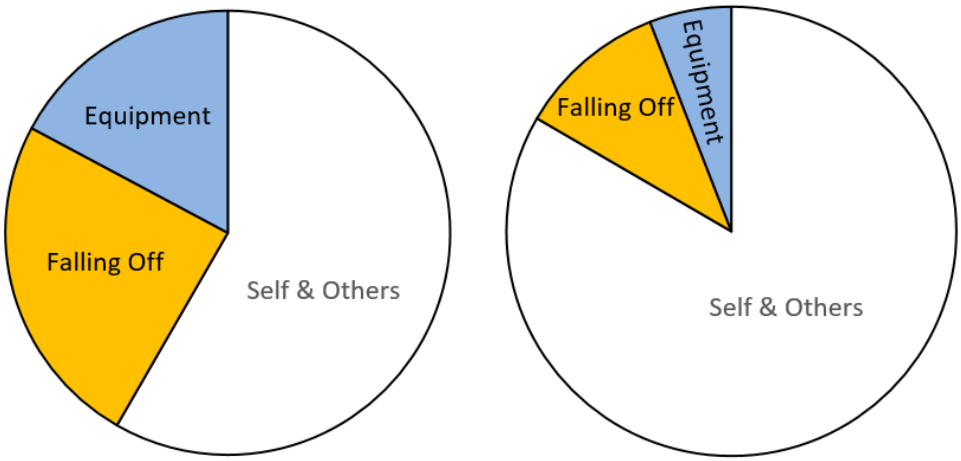

Figure 42: Research results showing the proportion of injuries attributable to the trampolines themselves (Ref 8)

10.0 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 body awareness and presents a healthy, real-world alternative to more passive pursuits like IT devices and television (Ref 9).

The major risk has always been the potential for injury from the trampoline design itself. The Springfree Trampoline 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.

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.

11.0 References

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5. Internal Research conducted by Springfree in cooperation with Zeitgeist 2019

6. Consumer Product Safety Council NEISS database: www.cpsc.gov product code 1233

7. ASTM F381 uses “Severity Index” which is a precursor to the HIC method. AS4989 and EN 71-14 use “G-max” which is the peak acceleration on impact. The set-limits of these different measures result in about the same as the HIC=1000 upper limit when used on trampolines. A document discussing this in detail is: Rolf Huber*, “Impact Attenuation Values and Prevention of Head Injuries in Children’s Playgrounds*”, Canadian Playground Advisory Inc. 2011

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