



In-Situ Testing of Impact Noise in Gyms – An Excitation Problem!

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ABSTRACT

The location of gyms within residential, commercial, educational and medical buildings usually requires impact generated noise from the gym to be mitigated to ensure that amenity of the building's occupants is not compromised. To facilitate this outcome, standardised guidelines for testing have been prepared by organisations such as the Institute of Acoustics and Association of Australasian Acoustic Consultants. Those guidelines contain assumptions about the usage of free-weights and equipment in a gym. To determine whether those assumptions are valid, a review of impact noise sources within a gym has been completed from the perspectives of a weight lifter, power lifter, bodybuilder, cross-fitter and long-term gym user. In-situ test results demonstrate how the choice of impact source results in a different outcome with respect to whether an adequate level of impact noise isolation is achieved or not.

1 INTRODUCTION

The evaluation of impact generated vibration and regenerated noise from usage of free-weights and equipment in a gym within an adjacent receiver property/occupancy is usually the hardest (and riskiest) acoustic assessment consideration for a gym or exercise facility. To facilitate this evaluation, guidelines such as the *AAAC Guideline for Acoustic Assessment of Gymnasiums and Exercise Facilities* (AAAC 2002) and *ProPG: Gym Acoustics Guidance* (ANC et al. 2023) have been prepared and other guidelines such as the ASTM WK90900 (ASTM 2024) are under development to aide acousticians in setting design criteria and assessing noise and vibration emissions.

In-situ testing is a critical step in determining whether the proposed impact isolation construction(s) will be effective in attenuating impact noise. In conducting the testing, the acoustician needs to use weights and drop heights that are consistent with those to be used in the gym (AAAC 2002; ANC et al. 2023). For their Method 2 testing, ANC et al. (2023) state that while generally the worst-case weights are around 35 kg for a dumbbell and 150 kg for a barbell, the weights used in the testing should be representative of the upper limit used by the strongest/most experienced gym users. This creates problems for the acoustician as in addition to finding a method to drop those weights from representative heights, occupational health and safety considerations can prevent that testing from occurring.

The frequency of occurrence of high levels of impact noise is another consideration. Due to the ongoing evolution in the way gyms are operated and exercises are conducted, it is not always the strongest/most experienced gym users that cause high levels of impact noise. Furthermore, impact noise is not always due to the lifting of free-weights and usage of exercise equipment.

The aims of this paper are to present some in-situ test results, theoretical discussion and observations on gym usage to help acousticians understand the complexities around impact noise in gyms.

2 THE PROBLEM

Potential problems around the in-situ testing of gym floors was identified during the testing conducted by the authors. A proposal to convert a disused 6,000 m² retail tenancy into a gym provided the opportunity to conduct in-situ testing of different gym flooring systems. The proposed gym location was directly above existing retail tenancies. The testing was requested in response to concerns raised by the shopping centre management whether the dropping of free-weights in the gym would cause nuisance.

A floorplan of the proposed gym with the test location indicated is presented in Figure 1. The spacing between the columns in Figure 1 is 7.6 m in the horizontal direction and 9.0 m in the vertical direction, with the suspended slab being approximately 400 mm thick. Due to the thickness of the slab, the project structural engineer advised that the maximum mass of the acoustic flooring system could be around 100 kg/m². This necessitated the investigation of rubber mat and lightweight floating floor options.

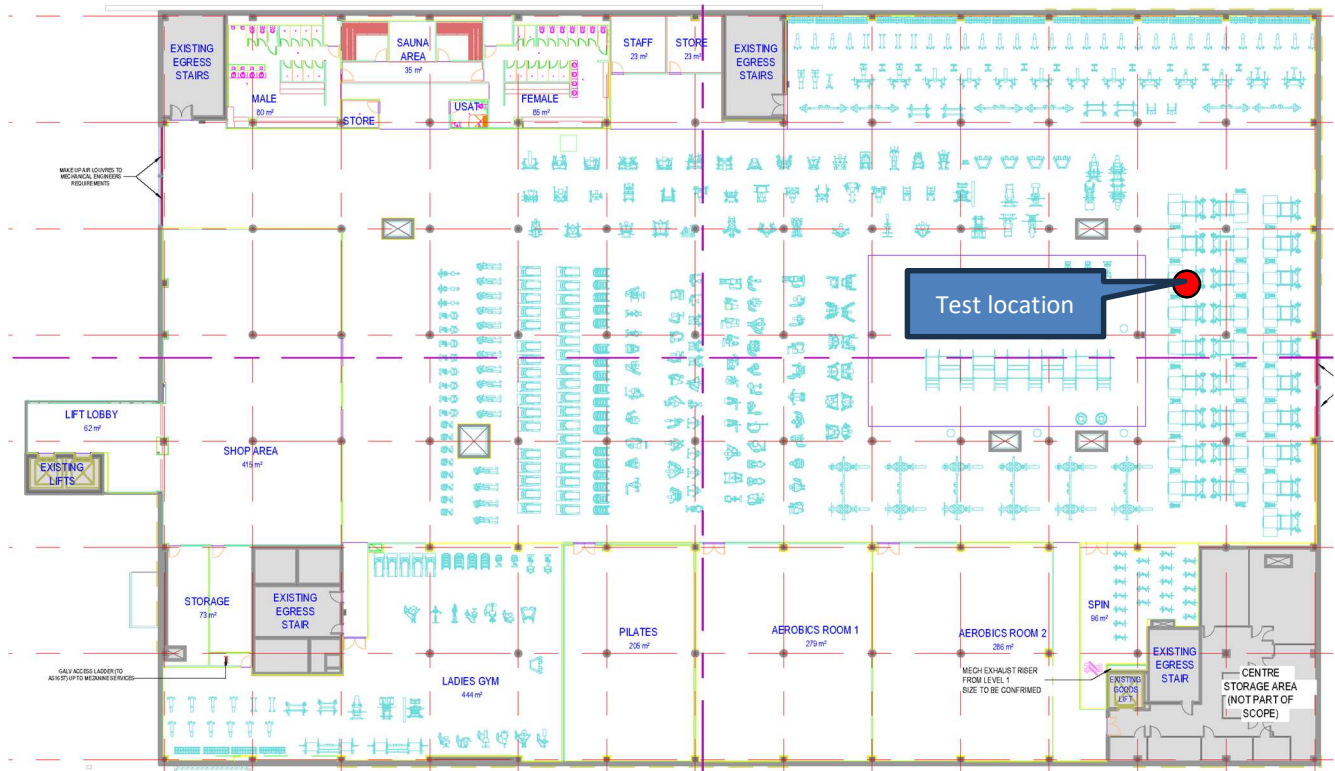


Figure 1: Proposed gym floor plan showing in-situ test location

Due to the large size of the gym and the risk of annoyance, permission was sought and granted to conduct testing dropping both a 45 kg dumbbell and a 100 kg barbell. Details of these sources are presented in Table 2. Each source was dropped at least five times onto each sample and the measured L_{max} levels averaged.

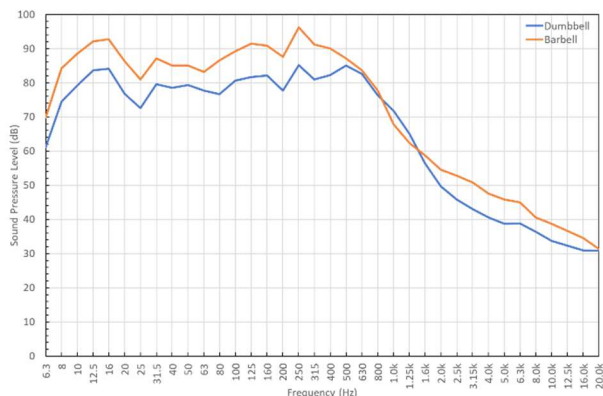
Table 1: Details of the weights used in the testing

Weight	Method	Mass (kg)	Drop Height (mm)	Kinetic Energy (Nm)
Dumbbell	Rolled off side of flat bench	45	430	190
Barbell	Deadlift drop	100	785	770

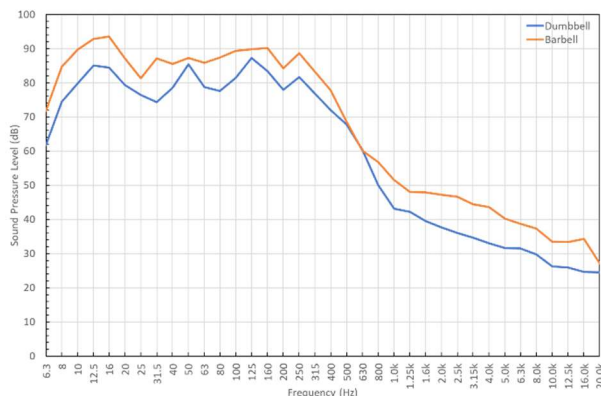
The rubber flooring samples were supplied by Regupol from their Everroll and Sonusfit ranges. The floating floor was constructed out of 2 x layers of 24 mm plywood measuring 1,200 mm x 2,400 mm with a superficial mass of 27 kg/m². Twenty equally spaced Mason Mercer IMF-D-510 damped springs were used under the floating floor.

The measurements results for eight different floors are presented in Figure 2 and Table 1. In each test the sound pressure level measured directly under the test location in the retail tenancy below was significantly higher when the barbell was dropped. Furthermore, in addition to the higher sound pressure level, the barbell impacts rattled the suspended ductwork and glassware on the shelves in the retail tenancy. This did not occur with the dumbbell drops, with the regenerated noise levels from the dumbbell drops barely audible over the background noise.

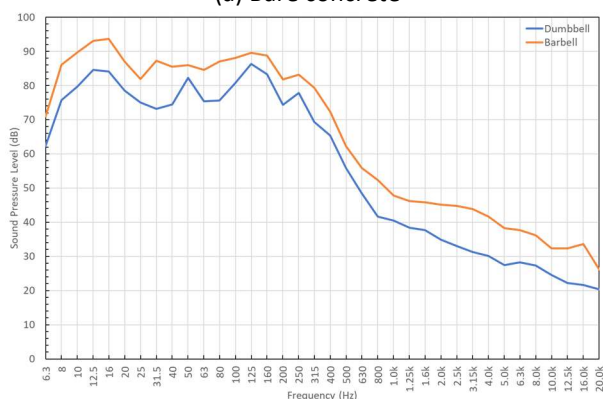
The original intent was to drop deadlifts of up to 200 kg onto the floor samples. However, testing with the 100 kg barbell revealed that the plywood floating floor jumped due to the impacts, causing springs to drop out of their rubber mounting cups and whiplash to the person dropping the weight. To increase the dead load of the lightweight floating floor, two layers of 18 mm CFC sheeting were added to give a superficial mass of 102.5 kg/m². Even with the addition of this extra mass and an additional dead load of over 200 kg, the lightweight floating floor sample



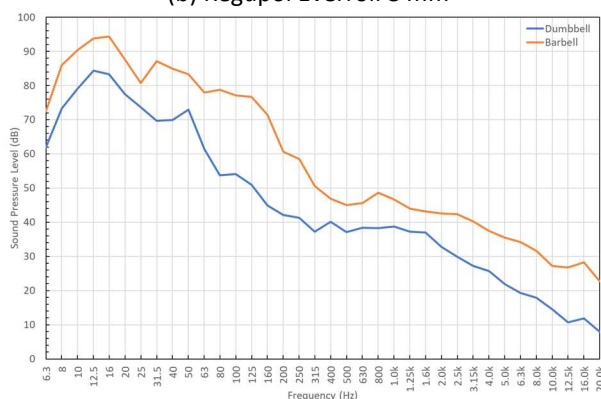
(a) Bare concrete



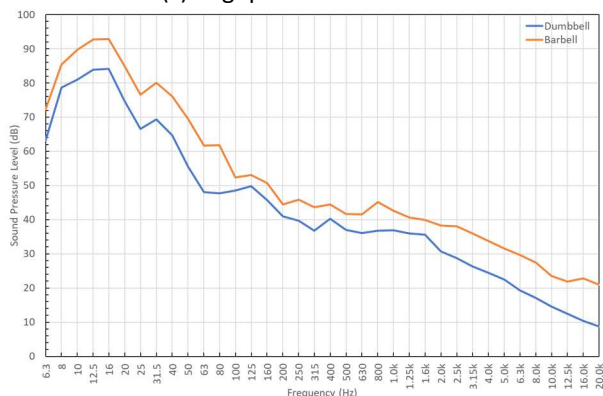
(b) Regupol Everroll 8 mm



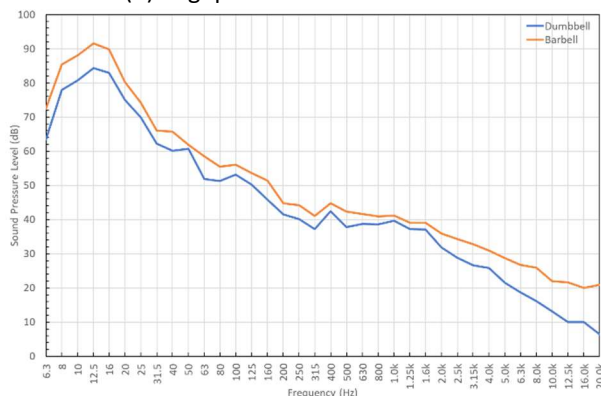
(c) Regupol Everroll 12 mm



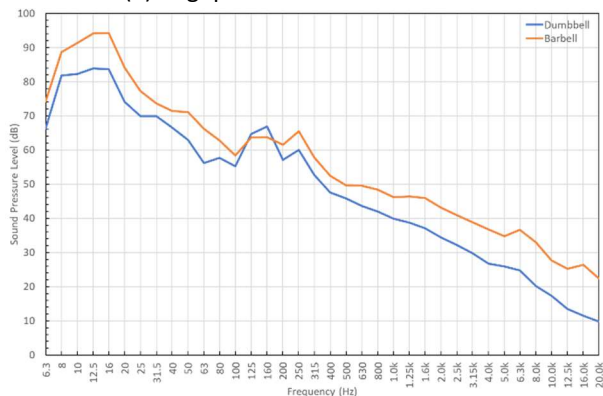
(d) Regupol Sonusfit m517 48 mm



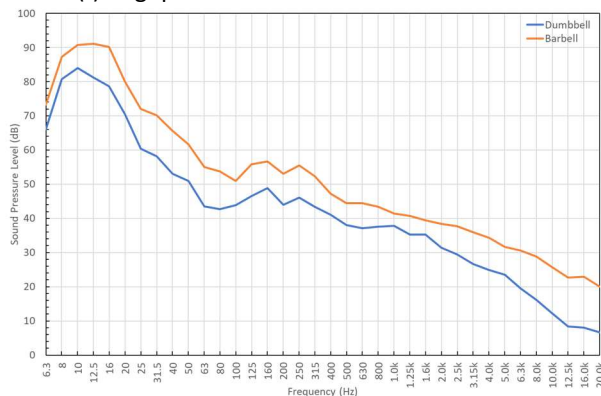
(e) Regupol Sonusfit m517 88 mm



(f) Regupol Sonusfit m517 88 mm + 48 mm



(g) Plywood floating floor



(h) Plywood floating floor + Regupol Sonusfit m517 88 mm

Figure 2: Comparison between $L_{\max}$ sound pressure levels for various dumbbell and barbell tests

Table 1: Comparison between the measured overall flat- and A-weighted L_{max} sound pressure levels

Floor	Dumbbell		Barbell	
	dB	dB(A)	dB	dB(A)
Bare concrete	95	87	103	92
Regupol Everroll 8 mm	96	80	102	84
Regupol Everroll 12 mm	94	76	101	81
Regupol Sonusfit m517 48 mm	90	49	101	65
Regupol Sonusfit m517 88 mm	90	47	99	52
Regupol Sonusfit m517 88 mm + 48 mm	90	48	98	50
Plywood floating floor	91	58	101	61
Plywood floating floor + Regupol Sonusfit m517 88 mm	89	46	98	54

still jumped, resulting in unacceptable occupational health and safety risks. Consultation with Mason Mercer determined that to provide adequate damping and edge restraint to prevent the floor from jumping, the test sample size would need to be increased to be at least 7.0 m x 7.0 m. A test sample floor was designed but the project was cancelled before it was built and tested.

The in-situ testing revealed that if the floor design was based on the dumbbell results, an unacceptable outcome would have been likely in the retail tenancies below. However, testing a heavy barbell is difficult due to the mass that must be lifted and dropped multiple times and occupational health and safety risks.

3 OTHER IN-SITU AND LABORATORY TESTS

Published journal and conference papers were sourced to for comparison against the weights and methodologies used in Section 2 as presented in Table 2. The results show that a range of different weights, masses and heights have been used, with large differences in the kinetic energy imparted onto the floor. With this type of variance, it is difficult to directly compare the test results to obtain meaningful trends (such as a consistent transfer function for the improvement a floor provides) that can be applied to the design of gym flooring systems.

Table 2: Sample weights and methods used for in-situ and laboratory gym floor testing

Source	Weight	Method	Mass (kg)	Height (mm)	Kinetic Energy (Nm)
Gartenburg (2014)	Bowling ball	Rolled off edge of timber stand	7	1,000	69
Hayne (2015)	Round dumbbell	Rolled off edge of flat bench	42.5	420	175
Cosstick et al. (2016)	Kettlebell	Dropped vertically	10	620	61
			6.8	1,300	87
			11.3	700	78
			13.6	900	100
			13.6	1,300	173
LoVerde et al. (2015)	Hexagonal dumbbell	Dropped vertically	22.3	700	153
			22.3	900	197
			22.3	300	21
			22.3	600	43
			7.3	700	50
			7.3	900	64
LoVerde et al. (2016)	Spherical steel shot	Dropped vertically	7.26	1,200	86
			7.26	700	50
			7.26	700	50
Gartenburg and Golden (2017)	Impact foot designed to	Custom-built drop tower	22.7	57	13
				289	64
				380	85

Source	Weight	Method	Mass (kg)	Height (mm)	Kinetic Energy (Nm)
Masoumi et al. (2018)	mimic 20 kg weight plate	Dropped vertically via cable release		760	169
			13.2	100	13
	Modified kettlebell		23.6	100	23
			17.3	500	85
			17.3	1,000	170
	Steel Ball	Dropped vertically		800	78
			10	2,000	196
			30	800	235
				2000	589
				200	23
			11.5	900	102
				1,500	169
Pinto et al. (2019)	Kettlebell	Dropped vertically via cable release		200	49
			25	900	221
				1,500	368
Hayne (2021)	Barbell	Deadlift drop	100	785	770
Buen (2021)	Round dumbbell	Rolled off edge of flat bench	40	420	165
	Barbell	Drop from hip	80	530	416
			3	500	15
Golden and Patzkw (2022)	Spherical steel shot	Dropped vertically		1,000	29
				500	29
			6	1,000	59
				500	36
			7.26	1,000	71
Rodrigues and Pinto (2022)	Round dumbbell	Dropped vertically	24	1,200	283
	Barbell	Deadlift drop	80	600	471

4 THE PROBLEM FROM FIRST PRINCIPLES

Insight into the problem of exciting a gym floor when conducting an in-situ or laboratory test can be obtained by completing a first principles analysis of the parameters that influence the impact force, F_I extant on a gym floor. F_I is dependent on:

- The kinetic energy (K) of the gym weight just before impact. K is proportional to the mass of the gym weight (m) in kg and the square of the impact velocity of the gym weight (v) in m/s, via:

$$K = \frac{1}{2}mv^2 \quad (1)$$

If the weight is dropped vertically the impact velocity is given by:

$$v = \sqrt{2gh} \quad (2)$$

where g is the acceleration due to gravity (9.81 m/s^2) and h is the height above the gym floor in metres. If the gym weight is given additional velocity by a gym user and/or mechanical leverage, the impact velocity and hence kinetic energy can be much higher.

- The angle of incidence (θ) at which the free-weight impacts the floor. When the angle of incidence (θ) is small, the impact force is reduced due to the increased distance over which the force is applied.

- The surface area over which the impact force is applied, which in turn depends upon the shape of the gym weight and the shape of the floor. A larger contact area between the gym weight and floor will result in a lower impact pressure, reducing the amount by which the surfaces compress.
- The elastic properties of both the gym weight and floor. For example, a plain metal gym weight is harder than a rubber coated gym weight and absorbs less energy upon collision, resulting in a greater impact force. The elastic properties of the floor will depend upon the choice of materials used for the floor, whether it is a lightweight or heavyweight floating floor, the isolators used under the floating floor etc.
- The surface roughness of both the gym weight and floor finish will affect the friction between the two surfaces and hence the energy transfer, particularly when the gym weight contacts the floor at an acute angle.

Environmental effects such as air resistance are negligible. Accurately modelling the interaction between the gym weight and floor is impossible, even if the elastic properties of both are known. While methods to predict the vibration and regenerated noise for heavyweight floor impacts have been formulated (ANC et al. 2023, Hopkins 2007), they generally provide an order of magnitude indication of potential effects. These methods also do not address vibrations travelling up columns to affect premises located above the gym and are hence limited to situations where the noise-sensitive premises is located below the gym.

Furthermore, if an empirical approach is adopted, in-situ or laboratory testing is still likely to result in a large level of uncertainty regarding the acceptability of a gym, as the test methodologies do not consider all of the factors that influence impact force.

5 A GYM USER'S PERSPECTIVE

Looking at the causes and control of impact noise from a gym user's perspective is helpful in understanding why impact noise is so difficult to simulate and/or predict. Additionally, understanding how gyms operate and gym user's think can assist in identifying potential mitigation measures to reduce both the severity and frequency of occurrence of impact noise.

5.1 Gyms and How They are Used are Evolving

When the first modern gym gyms were designed and constructed, the equipment in those gyms primarily consisted of free weights of various forms and equipment that was designed and constructed by the gym owner (Appleton 2021). Before the explosion in gym membership that followed the release of the documentary *Pumping Iron* in 1977, most gyms were independently owned and operated, with the gym owner overseeing the daily operations (Schwarzenegger 1998). This resulted in close supervision of the gym members to ensure that they were doing exercises with correct and proper form and an appropriate level of effort. For example, owners such as Vince Gironda, who opened his first gym in 1946, were known to terminate gym user's membership on the spot if they did an exercise incorrectly or did not put in enough effort (Appleton 2021). This is unlikely to occur nowadays, as gyms want to maximise their profits and terminating memberships whenever a member does something wrong is bad for business!

Currently, the gym industry is a crowded marketplace, with major chains competing against budget 24/7 gyms and boutique gyms that target niches such as functional training (Artbell 2025). With the exception of boutique gyms that offer a personalised training experience, supervision of clients working out is generally minimal or non-existent. Many commercial gyms now employ personal trainers as independent contractors who pay the gym for the opportunity to train clients on the premises (Duggan n.d.). As such, it is rare that gyms have staff members patrolling the floors to observe and correct patrons who are doing weight exercises incorrectly, which increases the likelihood of impact noise via failed lifts, poor technique etc. To minimise staffing costs and address the increasing fitness demands of modern urban populations, unmanned gyms, integrating advanced technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) are starting to emerge to provide flexible, personalised fitness solutions available 24/7 (Peng et al. 2025). Whether or not the technological innovations of unmanned gyms can be adapted to prevent impact noise remains to be seen.

Finally, since the COVID-19 pandemic, people returning to the gym have prioritised lifting weights and using exercise equipment they do not have access to at home rather than using stationary cardio machines (Meyersohn, 2023). This has led to a shift in how people work out, with more people doing high intensity training such as CrossFit and more lifting weights and squatting, particularly for women. This has forced some gym chains such as Planet Fitness to adapt their design to feature more dumbbells, squat racks and open areas for lunges, deadlifts and other weighed exercises (Mayersohn 2023).

5.2 Gym Layout and Finishes

It is quite common to find that getting the weight(s) into position for a lift or returning them to a rack after a lift is harder than the actual lift. For example, when replacing dumbbells on a rack, the dumbbell has to be swung away from the body of the person before being placed in the rack. This creates impact noise that cannot be avoided due to the mechanical leverage necessary to complete the movement.

The further a person has to move the weight across the gym, the more likely they are to make impact noise when they reach their workout location. For example, carrying one or two 50 kg dumbbells any distance is fatiguing and placing the dumbbells on the floor without causing impact noise difficult. This can be avoided by ensuring that the free weight area is not spread out unless there are multiple racks of weights available so that a person can pick the weights up from the rack and immediately commence the exercise.

The flooring used in the gym also has a big impact as a solid foundation is necessary when lifting to eliminate compressibility and the instability of squishy footing (Rippetoe 2011). Having a hard floor that is incompressible and unmovable is critical when performing lifts such as clean and jerk, snatch, deadlift and squat.

5.3 Equipment Selection

Poor equipment selection can result in higher levels or increased occurrence of impact noise. Removing or replacing exercise equipment with options more likely to result in lower levels of impact energy is possible in many instances. For example, the T-bar row in Figure 3(a) could be replaced by a supported T-bar machine, while the toaster rack weight plate holder (into which the weights are usually dropped) could be replaced with a weight stack.



(a) T-bar row



(b) Toaster rack weight plate holder

Figure 3: Examples of equipment selection that increases impact noise

Other examples to reduce the occurrence of impact noise include:

- Substituting an incline leg press (where the weight stops are oriented at 45° to the floor) with an arc leg press (where the weight stops are oriented parallel to the floor).
- Using safety straps rather than solid metal safety arms in power racks to increase the cushioning when a weight is dropped onto them in a failed lift.

5.4 Gym Etiquette

Gym etiquette has evolved over the last 100 years to include a number of unwritten rules that directly and indirectly influence impact noise, including:

- Focus on your own sets instead of other peoples, even if another person's form is terrible (Men's Health 2025). As such, unless a person asks about their form, unsolicited advice should not be offered. Thus unless the person has a personal trainer, staff members patrol the free-weight area to offer advice or the person is aware of their poor form, they will continue to lift in the same manner.
- If a gym has dedicated lifting platforms, bumper plates and no signs to the contrary, the dropping of barbells is acceptable (Reddit 2022). Hence if a gym is experiencing impact noise complaints, it should not provide lifting platforms or bumper plates that infer that type of lifting is acceptable. Furthermore, clear signage is needed to advise patrons that dropping of barbells (and other weights if necessary) is unacceptable.

5.5 Exercise Selection

In 1975, legendary bodybuilder Bill Pearl completed *Keys to the Inner Universe*, which was one of the first encyclopedias on modern weight training (Pearl, 1975). The aim of that book was to compile a complete training manual, illustrating nearly every basic exercise done with dumbbells/barbells and the most commonly used exercise machines in health clubs (Pearl and Schott 2015). If the same task was attempted today it would be near-impossible, due to the proliferation of gym equipment designed to work different parts of the body in isolation and fitness influencers on social media that promote variations of exercises that are claimed to be more effective than traditional strength exercises. As a result, new exercises appear in gyms overnight that have the potential to generate impact noise. An example of this type of exercise is the barbell hip thrust to work the gluteus maximus and medius. It is common to see gym members load up a 20 kg Olympic bar or a Smith Machine with six 20 kg weight plates as shown in Figure 4 to perform this exercise, with impact noise being generated as the weight plates contact the floor or the bars hits the Smith Machine stops.



Figure 4: A typical hip thrust setup on a Smith Machine

Some exercises require the weight to be dropped after lifting as attempting to lower it in a controlled manner risks injury. Gyms that allow exercises such as the clean and jerk, snatch, power snatch and deadlift will most likely have vibration and noise problems unless they are located in a stand-alone building. Other exercises that frequently result in high levels of impact force include squats, rack pulls and T-bar rows.

Compared to barbells, the dumbbell version of an exercise such as the bench press and shoulder press involves a greater amount of instability, which is inherent in have two separate weights waving around above your chest or shoulder (Rippetoe 2011). This is especially true when the weights used are sufficiently heavy to challenge the person's ability to finish the set. Because dumbbells are not tied together between the hands like a barbell, dumbbell presses require more active, conscious control, are hard to do and hence are more prone to failure of the lift where the person has no choice but to drop the weights for safety reasons.

5.6 Importance of Technique

Poor technique can lead to increased impact noise due to the increased likelihood of losing control of the weights and having them fall onto the floor or into the wall. Poor technique includes incorrect positioning of the weights before, during and/or after a lift, failure to maintain good posture during the exercise, incorrect head positioning, holding the breath causing vasovagal syncope (i.e.: blackout or fainting), failure to activate stabilising muscles, not using a spotter (or spotting someone incorrectly) when lifting heavy and not setting up or adjusting the equipment correctly prior to commencement of the exercise.

When using heavy weights, getting the weights into position before the lift and returning them to a position so that they can be safely returned to the ground, bench or rack is as difficult, or more difficult, than the actual lift. For example, if a person is not taught how to get the dumbbells into position safely and easily before a dumbbell bench press and to return them safely to the starting position on top of the thighs, they will be more likely to drop them onto the floor (Nilsson 2012).

Considering both the concentric and eccentric movements of a lift as part of the exercise is another common cause of weights being dropped. Concentric movements involve the shortening of the muscles as they contract. For example, lifting a weight during a bicep curl is a concentric action. Eccentric movements involve lengthening of muscles while they are under tension. For a bicep curl, this would involve slowly lowering the weight back down after completing the concentric movement of the exercise. When there is little or no control during the eccentric movement there is increased likelihood of the weight impacting the floor or, for pin weight machines, the weights smacking into the weight stack.

Finally, the effect of fatigue on technique and the ability to compete a lift should not be overlooked. If a person is attempting a maximal lift there is a likelihood of failure, where the only option to prevent injury is to drop the weight. In most instances when a lift fails, the person needs to impart a horizontal movement to the weight to ensure it does not drop onto their body. This will change the velocity and orientation of the weight as it impacts the floor.

5.7 Distractions

Distractions in the gym can take many forms including loud music/sounds, talking to someone in the middle of an exercise, people interrupting sightlines and the removing or returning weights to racks that are attached to the equipment being used. Generally, a person can eliminate those distractions by implementing measures such as wearing headphones while working out and using equipment in quieter areas of the gym. One distraction that cannot be eliminated is vibration. If vibration is allowed to be transmitted through the floor it can cause instability during the lift causing poor form and potential injury (Eleiko n.d.).

5.8 Ego and Attitude

Ego lifting, or lifting weights that are too heavy for one's ability, is probably the biggest generator of impact noise in a typical gym. Even a partial repetition using hundreds of kilograms will result in high kinetic energy entering the floor. Poor attitude and laziness also result in the generation of impact noise, as patrons, instead of placing the weights onto the floor, lowering the weight stack carefully, or lowering the weight back onto its stops gently, will deliberately drop or slam the weight/weight stack to make a loud noise and garner attention in the gym. These types of behaviour have become such an issue that Planet Fitness has a "Lunk Alarm", which is a siren triggered by aggressive or obnoxious behaviour like grunting, throwing weights, or flexing in a way that may be seen as intimidating to new gym members (Planet Fitness Info 2025).

6 SUMMARY

While guidelines have been prepared (and are in preparation) for the assessment of impact generated vibration and noise in gyms, it is clear that whatever prediction or in-situ testing methodology is used is unlikely to be able to replicate a gym. This creates a problem when there is a requirement to comply with emission criteria. More research is required into developing a suitable in-situ test methodology that is realistic, repeatable, safe and physically possible to complete.

By increasing the knowledge about how gyms are operated and incorporating a gym user's viewpoint into the analysis, it is possible to identify potential methods to reduce both the severity and frequency of occurrence of impact noise.

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