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Assessing the Level of Safety Provided by the Snell B95 Standard for Bicycle Helmets

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**ASSESSING THE LEVEL OF SAFETY PROVIDED BY
THE SNELL B95 STANDARD FOR BICYCLE HELMETS**

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Preface

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ASSESSING THE LEVEL OF SAFETY PROVIDED BY THE SNELL B95 STANDARD FOR BICYCLE HELMETS

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Abstract

The aim of this project is to assess whether the differences between the technical requirements and quality assurance approaches used by the Snell B95 and AS/NZS 2063:1996 standards for bicycle helmets are likely to result in significant differences in the level of safety provided by bicycle helmets manufactured to either standard.

The following approach has been used:

1. To review existing studies of bicycle helmet effectiveness, including those by Attewell et al, Henderson and Rivara et al, to assess the levels of injury reduction associated with helmets generally.
 2. Representative samples of helmets, to both standards, were acquired and tested in a laboratory environment with emphasis on simulating the helmet protective performance in real world crashes as defined in the review in Part1.
 3. Finally, consideration was given to the role of the quality assurance regime within the manufacturing process, and the need for some form of external quality assurance process conducted by independent testing laboratories.
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Keywords

Bicycle helmets, bicycle helmet effectiveness

NOTES:

(1) ATSB Research reports are disseminated in the interests of information exchange.

(2) The views expressed are those of the author(s) and do not necessarily represent those of the Commonwealth Government.

Executive Summary

EXECUTIVE SUMMARY

Changes have been made to the Trade Practices Act intended to legalise the sale in Australia of bicycle helmets meeting the American Snell B95 Standard. These changes have been made as part of the regular review of the mandatory consumer product safety standard for pedal cyclists under the Trade Practices Act 1974 as the current regulation, which was based on AS 2063.2-1990 and had become outdated, Department of the Treasury (1999). The State and Territory road authorities have not accepted the changes. Specifically, the road authorities have expressed concern regarding two areas:

- The lack of a quality assurance process for Snell-certified helmets on the Australian market; and,
- Whether the technical differences between the Snell B95 and AS/NZS2063 standards reflect significant differences in the level of safety provided by helmets to these two standards.

The aim of this project was to assess whether the differences between the technical requirements and quality assurance approaches used by the Snell B95 and AS/NZS 2063:1996 standards for bicycle helmets are likely to result in significant differences in the level of safety provided to the user. This was done by:

- Reviewing existing studies of bicycle helmet effectiveness;
- Testing representative samples of helmets to both standards; and,
- Considering the role of the quality assurance regime within the manufacturing process, and the need for some form of external quality assurance process conducted by independent testing laboratories.

The Snell Memorial Foundation is a not-for profit organization, which tests and certifies various kinds of helmets for use in specific activities. Snell uses a two-part process consisting of:

Certification Testing –The manufacturer submits sample helmets to Snell, which are subjected to the testing required by the Standard at a Snell laboratory. The helmet receives certification when these tests are completed successfully.

Random Sample Testing – The Foundation acquires samples directly from consumer sources such as retail outlets. The helmets are inspected and tested in the Snell laboratory to the requirements of the Snell standard.

In the USA the CPSC Regulation for Bicycle Helmets became law in 1998. The manufacturer or importer self certifies the helmet to the Regulation. As part of the certification the manufacturer is required to keep full records for three years of a “**reasonable test program**” in support of the certification and these must be available on call.

For a helmet to be certified to the AS/NZS 2036-1996 standard, it must pass the following set of requirements,

- **Manufacturers Quality Plan** audit by SAI-Global.
- **Type Testing** of samples of the production helmets by an accredited laboratory to the requirements of the standard. From this point the design of the helmet is frozen, any changes require a re-certification.

- **Batch Release Testing**, as production precedes each batch of the product is kept under bond and are not released for sale until a specified number of samples are tested.

The effectiveness of the bicycle helmet quality system currently in use in Australia is demonstrated by only one public recall of bicycle helmets (in 1998) occurring in the last five years, of a relatively small number of helmets. In the USA in the same time span 8 public recalls of a total of 331,900 helmets have been made. Recalls are relatively ineffective for maintaining safety of personal equipment, as it is difficult to get the publicity to the user effectively. The Snell Memorial Foundation has never successfully initiated and completed a recall against its range of voluntary standards.

Bicycle helmets have been proven to be effective in preventing head injury. Based on the research findings, it is possible to list the proven attributes required for an effective helmet design. The major research study supporting the factor is appended to the finding, often the attribute will have been mentioned in several studies.

- A helmet must be worn properly to be effective, Attewell et al (2001);
- Helmets are very effective in preventing skull fracture, but less effective in preventing brain injury, Henderson (1995).
- The helmet must remain on the head during the crash, Williams (1991);
- The helmet must remain in position during the crash, Williams (1991);
- The helmet must have the maximum possible coverage of the frontal and temporal areas of the head, Williams (1991), Cameron et al (1994) and McIntosh et al (1998);
- The helmet must have adequate energy attenuation characteristics, for a variety of impacted surfaces, including flat, blunt and sharp, Smith et al (1993);
- A drop energy requirement of between 1.5 and 2.2 metres appears to be adequate, Williams (1991) and Smith et al (1993);
- The criteria for the energy attenuation test should be in the region of 200g, McIntosh et al (1998);
- The helmet must retain its integrity during the impact, Ching et al (1997) and Williams (1991);
- The helmet must be retained, in case of a second impact, Williams (1991) and Smith et al (1993);
- A helmet with a hard shell appears to offer better protection from severe brain injuries, Rivara et al (1996);
- Severe brain injury occurs more often in impacts with other vehicles, McDermot et al (1993);
- The helmet for a young child needs to be different than for an older child or adult, Corner et al (1987).

Based on the review of the helmet effectiveness literature, there are several aspects of the helmet performance immediately before and during a crash, which need to be considered when reviewing the adequacy of a standard. These are grouped here into three requirements with a short explanation (with the related tests from the standard):

1. **The helmet must be worn.** A helmet must be worn to have any effect, must be attractive and comfortable for the wearer to be willing to wear it.
2. **The helmet must remain in place during the crash.** The retention system must be capable of keeping the helmet in place during the events immediately before (dynamic stability) and during (retention system strength) the crash.

3. **The helmet must have adequate energy attenuation.** The helmet must be capable of attenuating the impact to minimise injury. The helmet must cover the appropriate areas of the head; especially the frontal and temporal areas (test coverage). It must not disintegrate from the impact (helmet integrity) and must be capable of adequately minimising injury to the head resulting from impacts with different types of objects (energy attenuation and load distribution). The helmet must continue to remain in place on the head for a possible second impact (order of testing).

Nine different models of bicycle helmets were tested, with 6 helmets of each model submitted to the laboratory for testing to a combination of the AS/NZS2063 and Snell B95 standards tests. All the tests were performed after conditioning in the ambient environment. The following tests carried out and the findings were as follows:

- The **test area coverage** required by the two standards was similar for all the sizes of helmets, but the area of the head covered by the Snell certified helmets was greater. The more generous coverage of the Snell B95 helmets was also indicated by the slightly higher weights on average for these helmets.
- The **order of testing** followed AS/NZS 2063-1996, as this was the worst case from the two standards. The AS/NZS 2063-1996 standard requires the impact testing to be carried out before the retention system strength test on the same helmets. This effectively increases the severity of the retention system test as more deformation of the restraint system is likely to occur.
- The Snell B95 **dynamic helmet stability** test is significantly more demanding of the helmet design than the AS/NZS 2063:1996 static test. The Snell test takes the retention system of the helmet near to its mechanical limits.
- The **flat anvil impact energy attenuation** tests are included in both the AS/NZS 2036-1996 and the Snell B95 standards and were made on the front, rear, and top of the helmets. For these tests both group of helmets returned similar results. Further, it is clear that the higher energy of the flat anvil tests to the Snell standard generate a higher acceleration of the headform in this test for both groups of helmets, by about 25%. The safety margin built into the helmets to both standards easily deals with this increase in drop energy. Therefore the helmets to both standards offer the same impact attenuation protection and this is confirmed by the similarity in liner densities found for the range of models tested.
- The **kerbstone and hemispherical anvil impact energy attenuation** tests were only performed within the Snell B95 Standard. For both these tests the AS/NZS 2036-1996 approved helmets gave noticeably higher headform accelerations, with the average for these helmets exceeding the requirement of 300g. The test variability was also significantly greater for these tests on the AS/NZS 2036-1996 approved helmets. Two of the AS/NZS 2036-1996 helmets failed these tests with the kerb and hemi anvils.
- The sampled helmets certified to both standards gave very similar results in the **load distribution test**. If one of the AS/NZS 2036-1996 certified helmets, the Rosebank Ms 16, is removed from the test results, then the test variability is significantly reduced. This helmet still met the requirements of AS/NZS 2036-1996.
- The AS/NZS 2036-1996 certified helmets have greater **retention system strength** in comparison to the Snell B95 helmets. The average dynamic displacement for the Snell B95 certified helmets was close to exceeding the maximum limit of both AS/NZS 2036-1996 and Snell B95 standards.

- The **liner foam density** was consistent in all the helmet sizes and both certification standards, with the exception of the Bell Stryker helmet which was higher.
- The AS/NZS 2036-1996 certified helmets are consistently of lower **helmet weight** across the whole range of sizes than the Snell B95 certified helmets. This is a direct measure of the larger area of coverage of the head given by the Snell standard, as the foam density was similar for all the helmets tested, except for the Bell.

Overall, the comparison of the test results showed that the actual Snell B95 standard test requirements are slightly stricter than the requirements for AS/NZS 2036-1996 and have the potential to produce a slightly more protective helmet.

The six AS/NZS 2036-1996 certified helmet models when tested to AS/NZS 2036-1996 requirements for stability (6 tests/model), load distribution (6 tests/model), energy absorption (9 tests/model) and retention strength (3 tests/model) were subjected to a total of 146 tests of critical performance requirements for safety. The group was initially thought to have had 3 failures of the retention system strength, all by one helmet model, the Star SB-107. Enquiries determined that this helmet was not certified to the AS/NZS 2036-1996 standard, even though the sample helmets had the Standards mark. Therefore, there were no failures of the AS/NZS 2036-1996 certified helmets during testing.

The four Snell B95 certified helmet models when tested to Snell B95 certification requirements for stability (6 tests/model), energy absorption (15 tests/model) and retention strength (3 tests/model) were subjected to a total of 96 tests of critical performance requirements for safety. The group had 8 failures, made up of 2 failures to meet the stability requirements (2 helmet models), 4 to meet the retention system strength requirements (2 helmet models), possibly due to the order of testing used, and 2 to meet the hemispherical anvil energy attenuation test (one helmet model). The failures occurred to three out of the four helmet models tested. This gives a failure rate for the Snell B96 certified helmets of 75 % by model and 8.2 % by test. Two of these failures were significant and to one helmet model (the energy attenuation requirements), the other failures are minor but they were still failures to meet the requirements of two safety related tests.

The testing showed that helmets certified to AS/NZS 2036-1996 would perform as expected from the requirements in the standard. By contrast, the Snell B95 certified helmets had a lack of consistency in meeting the requirements of the Snell B95 standard. This lack of consistency is a clear indication of inadequate quality assurance during the manufacturing process. On the basis of this lack of consistent performance when tested, the sample of Snell B95 certified helmets were not capable of giving the level of protection expected from the requirements of the standard. At least eight percent of the sample of the Snell B95 certified bicycle helmets tested for this project would fail to protect the user to the level expected from the performance requirements of the standard.

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1. BACKGROUND

1.1. INTRODUCTION

Changes have been made to the Trade Practices Act intended to legalise the sale in Australia of bicycle helmets meeting the American Snell B95 Standard. These changes have been made as part of the regular review of the mandatory consumer product safety standard for pedal cyclists under the Trade Practices Act 1974 as the current regulation, which was based on AS 2063.2-1990 and had become outdated, Department of the Treasury (1999). Five years after the regulation was changed there are currently no helmets for sale to the consumers which only display certification to Snell B-95. Part of the reason for this situation is that each state has the authority to specify what is used on roads within their jurisdiction. All the states currently specify that only helmets that display evidence of certification to AS/NZS 2063 can be use on their roads. These changes have not been accepted and the road authorities have expressed concern regarding two specific areas:

1. The lack of a quality assurance process for Snell-certified helmets on the Australian market; and,
2. Whether the technical differences between the Snell B95 and AS/NZS2063 standards reflect significant differences in the level of safety provided by helmets to these two standards.

The aim of this project is to assess whether the differences between the technical requirements and quality assurance approaches used by the Snell B95 and AS/NZS 2063:1996 standards for bicycle helmets are likely to result in significant differences in the level of safety provided by bicycle helmets manufactured to either standard.

The following approach has been used:

4. To review existing studies of bicycle helmet effectiveness, including those by Attewell et al, Henderson and Rivara et al, to assess the levels of injury reduction associated with helmets generally.
5. Representative samples of helmets, to both standards, were acquired and tested in a laboratory environment with emphasis on simulating the helmet protective performance in real world crashes as defined in the review in Part1.
6. Finally, consideration was given to the role of the quality assurance regime within the manufacturing process, and the need for some form of external quality assurance process conducted by independent testing laboratories.

2. THE HELMET STANDARDS

2.1. INTRODUCTION OF SNELL B95 AS AN ALTERNATIVE AUSTRALIAN STANDARD

The following summary is based on the details in the web site, Department of the Treasury (1999), and discussions with a representative of the Department, Williams (2003). It is suggested that the website be visited for the full text.

In 1999 changes were needed to the Trade Practices Act 1974. The mandatory consumer product safety standard for pedal cyclists was based on AS 2063.2:1990, which had become outdated, Department of the Treasury (1999). AS 2063.2:1990 had been superseded, and all helmets on the market were now tested to the new standard AS/NZS 2063:1996. There was the possibility that some of the current helmets might not comply with the mandatory standard. Further, under World Trade Organisation agreements, the Commonwealth must ensure that its regulations do not impose unnecessary technical barriers to trade. For example, by setting a technical standard beyond the standards adopted by our trading partners, unless there can be shown to be genuine safety issues at stake, Department of the Treasury (1999).

Helmets complying with the past mandatory Australian standard (AS 2063.2:1990) had been shown to provide insufficient protection to certain areas of the head, particularly to the face, upper jaw, and temple, Williams (1991). The new standard (AS/NZS 2063.2-1996) had introduced a lower test line, which went some of the way to meeting the concerns about coverage of the temporal region of the head, Department of the Treasury (1999). The Department of the Treasury was unable to assess whether several other aspects of the past mandatory standard contributed to the safety of a helmet. The new Australian Standard required that the impact energy attenuation and load distribution tests were performed prior to the retention system test, specifically recognising that damage incurred in the earlier tests may affect the results of the retention system test. This order of tests is not specified in other standards. It was considered that the sequence of tests in the Australian Standard was sufficient enough to exclude a helmet from the Australian market. Similarly, there was no available accident data to assess whether the load distribution test itself contributed to the safety of a helmet user.

During the consultation process, an opinion often expressed was that if overseas standard offered equal or better levels of protection then there should be no objection to it being recognised as appropriate for the Australian market, Department of the Treasury (1999). However, there was also a common fear expressed that allowing helmets to other standards might result in a decline in levels of safety.

Of the available overseas standards, one of the standards maintained by the Snell Memorial Foundation (known commonly as the Snell B95) and the US Consumer Product Safety Commission standard were thought to be the closest to the Australian Standard, Department of the Treasury (1999). Further investigation showed that the CPSC standard did not offer a comparable level of safety protection due to the higher test line when compared with the Australian Standard. The Snell B95 standard on the other hand had a test line much closer to the Australian Standard.

The option of replacing the current mandatory Standard with a new regulation under the Act, which also allowed helmets certified to the Snell B95 standard, was felt to address all the performance requirements that are necessary for helmet safety, Department of the Treasury (1999). While involving some threat to local manufacturers who would have to compete with more imports, this approach was felt to allow the problems in the existing regulation to be resolved, as well as facilitating the ease and transparency of compliance and enforcement. It also took account of trace harmonisation with New Zealand, in accordance with the Trans Tasman

Mutual Recognition Arrangement, and with other countries recognising the broad aims of the World Trade Organisation of which Australia is a member.

2.2. THE SNELL B95 STANDARD FOR PROTECTIVE HEADGEAR FOR USE IN BICYCLING

Snell currently publishes standards for protective headgear for use in automotive racing, carting, motorcycling, bicycling, non-motorized sports, harness racing and equestrian sports, competitive skiing and snowboarding. Snell randomly selects for testing certified helmets in the market and informs the manufacturer if there were any failures in the testing. Any such failures potentially require a recall and so are very difficult for a manufacturer to deal with. This process is designed to force the manufacturer to be careful about quality control, but no such recalls are on the public record, BHSI (2002) and SAI Global (2004).

A Snell standard is usually set to a higher performance requirement than other current standards found worldwide. In the early and mid 1990s, the Snell B90 Bicycle Helmet standard was the de facto standard and virtually every bicycle helmet sold in North America and Europe was able to meet it.

Snell revised its bicycle helmet standard in 1995, with the Snell B95 standard taking effect in September of 1995, Snell (2003). The requirements of the standard are summarised in the Appendix 1. The B95 standard requires slightly more coverage of the head and has slightly higher energy absorption requirements than the previous B90 standard. Snell permitted manufacturers to continue using the B90 standard, accommodating those whose current production was unable to meet the new standard. More recently Snell has modified the test methodology in both these standards to match that used in the new CPSC Regulation CPSC (2003). The CPSC Regulation is equivalent to the Snell B90 standard, BHSI (2003). It has done this to allow a common test methodology for the US market.

A helmet model to be certified to any of the Snell helmet standards must comply with the following test programs:

Certification Testing – An official pre-market evaluation for the Snell Certification of the helmet. The manufacturer submits sample helmets to Snell, which are subjected to the testing required by the Standard at a Snell laboratory. There is at present only one laboratory. Snell only issues certification of the helmet when these tests are completed successfully.

Random Sample Testing – An official follow-up evaluation required for all certified helmets. The Foundation acquires samples directly from consumer sources such as retail outlets. The Snell Certified helmets are inspected and tested in a Snell laboratory to the requirements of the Snell standard. If a helmet fails, three further samples are purchased and tested to confirm the findings of the first test. If any of these three helmets fail Snell will demand that the manufacture to discontinue production of these helmets as a Snell certified products.

The newer Snell B95 standard has continued in parallel with the older Snell B90 standard. Both standards have been upgrade to keep the test requirements similar to the US Consumer Product Safety Commission CPSC Regulation, which was becoming mandatory. In North America, a helmet complying with Snell B95 is considered a “premium” helmet to the toughest standard, BHSI (2002). By the first half of 2003, though there are many helmets listed by Snell as certified to Snell B95, it had become very difficult to purchase such a helmet in North America retail outlets, Pedder (2003) and Thom (2003).

The Snell Standard is anti-competitive in the Australian context, as other bodies are not able to certify to the Snell Standard, while other bodies can certify to AS/NZS 2036, SAI-Global (2004).

Snell maintains that the random sampling approach to ensuring the quality of helmets on the market is effective, Becker (2003), but for reasons of client confidentiality was not able to support the statement with any statistics or information regarding discussions with helmet manufacturers and importers and resulting actions taken. The random sampling of helmets by Snell at present only takes place in North America and Europe. Discussions have taken place between Snell and various groups in Australia for implementing a random sampling process in Australia and New Zealand, but again due to client confidentiality, problems with sharing of test information were unable to be resolved, Becker (2003). Some helmets have been collected in Australia and tested by Snell for the Australian Consumer and Competition Commission. Snell has since indicated that it would not be involved in such a process unless it had full control of the information and responses generated.

2.3. OTHER BICYCLE HELMET STANDARDS IN THE USA

This section is presented to give some perspective on the North American environment in which Snell operates. In 1984 the standard used in the USA was the ANSI Z90.4 Bicycle Helmet Standard, which was self-administered. As a result, user groups began to suggest that this standard had to be supplemented by the Snell B85 standard, which became accepted world wide as the best standard. The original Snell B90 Standard superseded the Snell B85 Standard in 1990.

At the end of 1994, Bell Sports, then producing half the world's production of bicycle helmets, stopped using Snell to certify its bicycle helmets. Instead they turned to the new American Society of Testing of Materials (ASTM) F1447 bicycle helmet standard with certification by the Safety Equipment Institute (SEI). The SEI is a non-profit organisation, which developed a certification process for bicycle helmets to the ASTM standard. This process used a third party helmet test laboratory (ETL Testing Labs, NY) for certification and regular batch testing and a rigorous quality control regime for the helmet manufacturer, which included batch testing and a yearly factory inspection. The aim of the quality process was to ensure that substandard product runs did not reach the retail outlets, BHSI (2003). At the time, a Snell certified helmet (to Snell B90) did not offer a significant performance difference from a helmet meeting the ASTM standard and certified by SEI. The main difference for the helmet manufacturer was in the certification procedure, which was aimed at ensuring that a substandard helmet were not released to the public by making the manufacturer's own production quality control process more rigorous. These voluntary changes by Bell Sport and other US based manufacturers were to reduce costs of certification and to control product liability claims.

At the same time in 1994 the US Congress requested the US Consumer Product Safety Commission CPSC to develop a US Government Standard for bicycle helmets. The CPSC Requirements for Bicycle Helmets became law in 1998 and covers all helmets produced after 1999, CPSC (2003).

The CPSC Regulation is equivalent to the Snell B90 and the ASTM F1447 standard, BHSI (2003). It is based on many of the test methods originally formulated by the ASTM Helmet Committee. The quality assurance requirements are defined in the Regulation, and strictly enforced.

The manufacturer or importer self certifies the helmet to the CPSC Regulation, CPSC (2003). As part of the certification the manufacturer is required to keep full records for three years of a **“reasonable test program”** in support of the certification and these must be available on call. As part of this “reasonable test program” the bicycle helmets produced by the manufacturer must be divided into production lots and sample helmets tested from each lot. Whenever a change occurs in parts suppliers of parts or production methods then a new production lot must be

established. The system has similarities to the process required for all bicycle helmets sold in Australia up until 1999, with the following exceptions:

- The system is self administered by the manufacturers and distributors;
- There is no audit of the quality program of the manufacturer;
- The records are only kept for 3 years not 10 as is required in Australia.

2.4. AS / NZS 2063:1996 PEDAL CYCLE HELMET STANDARD

The certification methodology used for the Australian Standard AS/NZS 2063 is based on internationally accepted best practice as defined in ISO Guide 65 Requirements for bodies operating product certification systems, and the implementation of this system is supervised by JAS ANZ, an Australian and New Zealand government agency. The certification system used for the Snell Standard is not under this form of supervision, nor does it comply with the same level in ISO Guide 65, ISO (1995). For a helmet to be certified to an AS/NZS standard by SAI-Global, it must pass the following set of requirements, SAI-Global (2003).

1. **Audit of the Manufacturers Quality Plan** This audit focuses on the quality plan used by the manufacturer for the certified product. This is generally similar to the ISO 9000 requirements, see the following Section. The quality plan ensures that the design and manufacture of the helmet is to a certified quality standard with the requisite controls on the inputs and outputs.
2. **Type Testing** Samples of the initial production batch of the helmets are tested by an accredited laboratory to the requirements of the Standard. From this point the design of the helmet is frozen, any changes require a re-certification of the helmet.
3. **Batch Release Testing** As production precedes each batch of the product is kept under bond and are not released for sale until a specified number of samples are tested. If a significant change in materials or the supply of components occurs then a new batch must be started.

All samples sent for certification type testing to AS/NZS 2063-1996 are independently selected from a minimum production run of 50 pieces; all batch test samples for new models are independently sampled at a rate of 4/400 for the first ten batches, SAI-Global (2004). If no problems are found during this period the sampling rate is lifted to 4/1000. If during future batch testing a helmet fails any clause of the standard a retest of 8 samples is allowed, if the helmet still fails on retest the batch is scrapped. The result is that all Standards Mark labels are removed and the sample rate then returns to 4/400 for the next 5 batches to ensure the problem does not recur.

This continuous monitoring of the production aims to ensure that:

1. The design meets the requirements of the standard;
2. The manufacturing process remains consistent; and,
3. No changes are allowed to the product that may cause the product to fail to meet the standard with out a re-certification of the helmet.

By this means it is aimed to ensure that only compliant products reach the Australian end user.

The AS/NZS 2063-1996 Standard has several other areas that are not accepted as necessary by some manufacturers.

In Australia in the late 1980s, due to the increasing use of vented and non-shelled helmets bicycle helmets, the penetration test was replaced in the AS 2063.2-1990 version with a test to assess the capability of a helmet to distribute the load of an impact by a kerb anvil. This decision was made based on the work of Long et al (1986). The Australian Standard is the only standard, other than the bicycle helmet standard used by the Swedish Consumer Agency Konsumentverket, which contains a load distribution test.

The AS/NZS 2063-1996 Standard was prepared to supersede AS 2063.1—1986 (in part), AS 2063.2—1990 and NZS 5439:1986. The requirements of AS 2063-1996 were an intermediate step towards a complete re-evaluation of the performance and design requirements of helmets for pedal cyclists. The changes were based on Australian bicycle accident investigation research, Williams (1991), McDermot et al (1993) and McIntosh et al (1995). The load distribution test of the Australian Standards has been seen as being a high point that distinguishes the Australian bicycle helmet standard from overseas standards, BHSI (2003).

A supplier of US-manufactured helmets objected that this particular test has failed ‘high performance’ helmets that are approved elsewhere in the world, Department of the Treasury (1999). Snell also objects to the inclusion of test methodologies in the Australian standard, which differ from those more commonly, used in North America, Becker (2003). However these are extremely parochial views, when placed in the context of the other major bicycle helmet standard used in Europe. This standard, EN 1078:1997 Helmets for pedal cyclists and for users of skateboards and roller skates, makes use of the test methodology developed for the ECE 20.5 motorcycle standard and is almost totally different in test methodology. As an example of the scope of the differences the impact energy attenuation drop test uses a free flight headform with a triaxial accelerometer and this requires a significant change in all aspects of testing of the helmets.

The AS/NZS 2063-1996 uses static retention system strength and stability tests. The revision of the standard, which does include dynamic stability and strength tests, is expected to be issued in mid 2004.

The AS / NZS 2063:1996 Pedal Cycle Helmet Standard has a required test order. During the testing for AS / NZS 2063:1996 the samples are first impacted and then the same samples are required to be able to pass the retention strength test. The Snell B95 uses a new helmet for each test; this reduces the perceived differences in test requirement severity.

3. HELMET RECALLS

The production lot system or batch release process is aimed at stopping a non-conforming product reaching the market. This process is not unique to protective equipment such as helmets, but used by all manufacturers who have strict quality assurance controls in place, such as required by ISO 9000. When a non-compliant helmet does manage to get into the market and fails to meet the appropriate standard then a recall may be required.

In Australia public recalls of helmets have occurred infrequently, due in large part to the batch release process enforced by SAI Global as part of the Standards certification process. A well known failure of this process did not involve bicycle helmets, but an Australian manufactured motorcycle helmet. In this case the Australian Competition and Consumer Commission (ACCC) enforced a major product recall of the Eldorado Motorcycle helmets under Section 65C of the Trade Practices Act 1974, ACCC (1999). This portion of the Act requires a manufacturer of products, which have a current mandatory Australian standard not to manufacture or sell that product unless it complies with that standard. Four other motorcycle helmets models have been recalled as well all for failing to comply with the mandatory standard, but only one bicycle helmet model. The bicycle helmet concerned, the “team Issue”, failed the impact test of the AS 2036.2-1990 and was recalled in 1998, PRC (1998). When the difficulties with this helmet model were raised, the importer (Target) quickly recalled the helmet.

More usually in Australia such problems have been found before the product reaches the market, by either the helmet batch release process or the requirement to have controls on the quality of all materials going into the production process. It has been difficult to obtain details of instances where action of this type has been taken for reasons of client confidentiality. Similarly Snell was unable to comment on recalls or approaches to manufacturers to address problems for the same reason of client confidentiality, Becker (2003).

The largest manufacturer of bicycle helmets in Australia, Rosebank P/L, was more willing to comment, Mallaby (2003). They feel that their quality system, which complies with the SAI Global requirements, ensures that defective helmets do not get to the market. Problems with their helmets are found during the production process and are not allowed out into the market place. The problems get caught early in the system by the quality assurance process in force for the company products required by its Product Compliance Program for SAI Global.

The U.S. Consumer Product Safety Commission does publicise official helmet recalls and these are listed in Table 1, CPSC (2003). These recalls are the only data publicly available of the necessity for requiring and enforcing recalls on bicycle helmets. Most of the recalls were classified as voluntary on the part of the manufacturer, who self certify the helmets to the CPSC Regulation. There may have been other recall actions by manufacturers themselves that were not reported, particularly of product still in the distribution channels, and before CPSC had a standard for bicycle helmets in place.

The CPSC may decide not to force a recall of a helmet that fails the standard by only a small margin. A manufacturer whose helmet tests at 330g instead of the maximum permissible 300g may be instructed to improve the product and permitted to keep selling it, BHSI (2003).

Table 3.1. Public bicycle helmet recalls by the US CPSC, CPSC (2003). The recalls are listed with the most recent first.

Date	Helmet Models	Numbers	Reasons
22/5/2003	Catlike "KompactTM"	2250	Failed impact testing required under the CPSC safety standard for bicycle helmets, violating the Consumer Product Safety Act.
18/3/2003	MOSA Sports "Five 40"	1250	Failed impact testing required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
17/11/2000	Variflex "X-Games Aggressive"	240000	Failed impact testing required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
17/11/2000	NHS "TSG Metallic Gold"	1100	Failed impact testing required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
	"TSG Gloss Black"	1000	
	"TSG Foundation Blue"	500	
17/11/2000	First Team Sports "Guardian Junior Helmets"	1000	Failed impact testing required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
5/7/2000	Rand International "L.A. Crusin'"	70000	Failed impact testing and labelling required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
5/7/2000	Cycle Express "Hearts and Flowers"	9000	Failed impact testing and labelling required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.
29/4/1999	Bell Sports "Bellistic" "Rhythm" "Qualifier"	5800	Defect with helmets' chinstrap rivets can result in the helmet coming off the rider's head in the event of a fall or crash. Bell Sports is aware of one incident where the chinstrap assembly became detached from a helmet during a crash.
7/1995	Jaguar "3060"	25000	Failed impact testing required under the CPSC Safety Standard for Bicycle Helmets, violating the Consumer Product Safety Act.

It is of note that the recalls of all these helmets were due to failure to meet the test requirements of the regulation, either the impact attenuation or the retention system strength. These are failures that would be found by a rigorous batch release test system before the helmets reached the market.

The large number of these recalls highlights another problem regarding the logistics of ensuring that the recall information gets to the consumer and is then acted upon to remove the product from use. The use of a recall is a very poor as a means of ensuring the safety of helmets on the market.

4. HELMET EFFECTIVENESS REVIEW

4.1. INTRODUCTION

A survey of the available literature was made with respect to the effectiveness of wearing a bicycle helmet in reducing fatality and injury. The literature split itself into three parts:

1. Using mass data from hospital and accidents for statistical analysis of the effectiveness of wearing a helmet, the majority of studies in this type were summarised in a meta analytical study by Attewell et al (2001);
2. Using the results of detailed accident investigation including inspection of the helmets used (and testing); and,
3. Investigation of other factors important in promoting helmet wearing.

4.2. MASS DATA STUDIES

4.2.1. Attewell et al (2001)

In a study for the ATSB, Attewell et al (2001) quantified bicycle helmet efficacy using a formal meta-analytic approach based on peer-reviewed studies. A literature search was conducted using Medline and a total of 16 articles met the selection criteria of the protocol used. This study is included here in some detail as it effectively summarises many of the available studies using the analysis of mass data.

The earliest article was by Dorsch et al., (1987) involving an Australian study of recreational cyclists who replied to a mailed questionnaire concerning injuries sustained in bicycle crashes over the past 5 years. Two other self-report surveys were also conducted in the US by Wasserman et al., (1988), Wasserman and Buccini, (1990). All the remaining studies were based on cyclist presentations at hospital emergency departments in Australia (McDermott et al., (1993), Thomas et al., (1994) and Jacobson et al., (1998)), Canada (Finvers et al., (1996) and Linn et al., (1998)), the UK (Maimaris et al., (1994)) and the US (Thompson et al., (1989, 1990, 1996a & 1996b), Rivara et al., (1997), Spaite et al., (1991) and Shafi et al., (1998)).

Efficacy odds ratios (OR) for head injury were computed from data extracted from 13 studies. Twelve out of 13 studies showed a large protective effect (OR 0.0 - 0.6). Shafi et al., (1998) was the only study with a higher rate of head injury among the subjects (children) wearing helmets compared with non-helmet group (68% vs. 60% OR = 1.37). However, this difference was not statistically significant.

The heterogeneity test across the selected studies is statistically significant ($Q = 52$ on 11 df, $P < 0.001$). The random effects estimate of the summary odds ratio for head injury is 0.40 with 95% confidence interval (0.29, 0.55). Thus, it is estimated that helmets reduce the risk of head injury by 60%.

Efficacy odds ratios (OR) for brain injury were computed from data extracted from 8 studies. All but one of the studies showed a large protective effect (OR 0.0 - 0.6), though not all results were individually statistically significant. Again Shafi et al., (1998) was the only study with a higher rate of brain injury among children wearing helmets compared with the non-helmet group (68% vs. 54% OR = 1.77).

The heterogeneity test across the 8 selected studies is statistically significant ($Q = 22$ on 7 df, $P < 0.002$). The random effects estimate of the summary odds ratio for brain injury is 0.42 with 95% confidence interval (0.26, 0.67).

Six studies provided estimates of helmet efficacy for facial injury. All odds ratios are less than one, but not all are statistically significant. One study (Maimaris et al., (1994)) included facial and neck injury as a combined group. Some studies included minor injury. Thompson et al., (1990) and Thompson et al., (1996a) excluded cyclists with head injury from the control group. Their latter study (1996a) also provided three separate estimates for the upper, mid and lower face, giving strong evidence for a decreasing protective effect from the helmet rim. Combining the Thompson et al., (1996a) result for the upper face with results from the other studies concluded in a statistically significant heterogeneity test ($Q = 11$ on 5 df, $P = 0.04$). The random effects estimate of the summary odds ratio for facial injury is 0.53 with 95% confidence interval (0.39, 0.73). Even after using the more conservative estimate for the lower facial injury of Thompson et al., (1996a) instead of the estimate for the upper face, the result is still statistically significant (0.67 with 95% confidence interval (0.51, 0.87)). In another study by Thompson et al., (1998), they concluded that helmet use reduces the risk of injury by 85%, brain injury by 88%, and severe brain injury by at least 75%.

In regards to neck injury, there were only three studies with sufficient injury details to compute an efficacy estimate for neck injury (Wasserman and Buccini, (1990), McDermott et al., (1993) and Rivara et al., (1997)). All showed a greater incidence of neck injury among the helmet wearers, but the odds ratio was reduced to less than one on adjustment for age. The combined estimate was not strictly statistically significant (1.36 with 95% confidence interval (1.00, 1.86).

Six studies reported results for fatal injury. In each study, the percentage of fatally injured cyclists among those wearing helmets was less than those not wearing helmets. The combined estimate for the odds ratio for fatal injury for helmet wearers versus non-helmet wearers was also statistically significant (0.27 with 95% confidence interval (0.10, 0.71).

The Attewell et al (2001) study clearly confirmed the benefits of helmets in terms of injury risk. The upper bounds of the 95% confidence intervals provide conservative risk reduction estimates of at least 45% for head injury, 33% for brain injury, 27% for facial injury and 29% for fatal injury.

4.2.2. Other Studies

In another review paper by the Council of Scientific Affairs, American Medical Association (1994), some of the same studies as used by Attewell et al (2001) were included. The study of the injuries of 191 bicyclists was discussed (Wasserman and Buccini, (1990)). Only one of 109 injured bicyclists wearing helmets in this study sustained a skull fracture, whereas 11 of 82 injured bicyclists not wearing helmets sustained skull fractures. In another study of 173 persons dying from bicycle-related injuries in Miami, according to autopsy findings, 159 victims had serious head and neck injuries (Fife et al. (1983)). Of the 159, 110 had skull fractures and 90 had brain contusions. None of the 159 bicyclists with serious head injuries was wearing a helmet. According to two case-control studies (Thomas et al. (1994) and Thompson et al. (1989)), wearing a helmet reduces the bicyclist's relative risk of head injury in a crash by 63% to 85%. The two research groups concluded that using helmets decreases the risk of loss of consciousness or brain injury as the result of crashes by 86% or 88%.

In a study by Linn et al (1998), results were obtained over 5 years from 1462 injured bicyclists ages 1-19. More than 70% of injured bicyclists reported no helmet use. The proportion of admissions of injured bicyclists who did not use helmets was always higher than the proportion of admissions of those who used helmets (OR=2.23, CI=1.39-3.62). Head and face injuries occurred more often among those who did not use helmets (OR=1.55, CI=1.18-2.04). However, there was no excess of minor head injuries among non-users (OR=1.10, CI=0.60-2.06). Of the 62 concussions, 57 occurred to non-helmet users (OR=4.04, CI=1.55-11.47).

In a study performed by Bjornstig et al (1992) data were taken from 843 injured bicyclists involved in non-fatal cases, where 321 (38%) were unhelmeted. 100 (31%) individuals sustained cerebral concussion (n=97) or contusion (n=3). Of these 100, 17 had impact point visible outside and 54 inside the protective area of a helmet. In 29 cases there was no focal injury objectively indicating the point of impact. The impact point was stated by 15 of the subjects to have been within the area covered by hair, indicating that a helmet might have been able to reduce the impact force in these cases. In the remaining 14 cases it was not possible to determine the impact point. Thus, at least 69 (69%) of the persons with cerebral concussion or contusion might have had the impact force reduced if they had worn a helmet.

The abrasions and lacerations of the skin (n=160) and superficial contusions of the head and face (n=89) were localised within the area protected by a helmet in 97 (39%) cases together.

As a conservative estimate, the use of a conventional bicycle helmet could be expected to have reduced 170 (43%) of all 394 non-fatal head and face injuries. Altogether, 155 (48%) persons might have had a reduction in injury if a bicycle helmet had been used.

For fatal cases, data were taken from 105 cases during a 10-year period. In 67 persons (64%), the head injury was considered the sole cause of death. All injuries were from blunt impact. In 43 cases (64% of the 67 fatalities) with a head injury as the only cause of death, a helmet might have reduced the severity of the injuries. This indicates that 41% of all 105 fatally injured bicyclists might have experienced an injury reduction.

Finvers et al (1996) performed a study to identify bicycle-related injuries in children and the effect of helmet use on injury patterns and prevention. Separate bicycle accidents (n=699) were recorded resulting in 856 injuries. Only 13.7% of children were wearing helmets and 76 serious head injuries were recorded. The risk of serious head injury was significantly greater when a helmet was not worn (χ^2 0.01 < p < 0.05). This represents an odds ratio of 3.12 (95% CI = 1.13-8.75). There was no significant difference in terms of serious injuries overall comparing helmeted and non-helmeted children (OR = 1.11; 95% CI = 0.72-1.72).

In an Australian report on helmet effectiveness authored by Henderson (1995), the 1995 Victorian data indicates that 25% of bicyclists admitted to hospital, and 44% of those killed, had head injury as their single most important injury. These figures do not include multiple injuries, many of which are unrecorded head injuries. Head injury is a cause of death in 80% of the deaths to cyclists and 33% of the reported injuries in Victoria. Nationally official figures show that deaths among bicyclists have fallen from around 100 each year a decade ago to about half that number. Most of the fall has occurred in the years since 1989. The most careful, conservative estimates show that the reduction in risk of head injury to a bicyclist as a result of wearing a helmet is in the order of 45%. Other estimates from controlled studies all over the world gave even higher risk reduction figures, ranging from 45% to 85%. For children, an Australian study showed that the risk of injury is reduced 63% for head injury and 86% for loss of consciousness, when a helmet is worn.

Maimaris et al (1994) studied the circumstances of bicycle accidents and nature of injuries sustained, to determine the effect of safety helmets on pattern of injuries. There were 1040 patients with complete data presenting to the department in one year with cycle related injuries of whom 114 had worn cycle helmets when accident occurred. Head injury was sustained by 4% of helmet wearers compared with 11% of non-wearers. Mutually adjusted odds ratios showed a protective factor of 3.25 (1.17 to 9.06, P = 0.024) for wearing a helmet.

McDermott et al. (1993) evaluated the efficacy of helmet use by comparison of crashes and injuries in 366 helmeted (261 Australian Standard approved and 105 non-approved) and 1344 unhelmeted casualties treated from 1987 through 1989 at Melbourne and Geelong hospitals or dying before hospitalisation. Head injury occurred in 21.1% of wearers of approved helmets and 34.8% of non-wearers (p < 0.001). The relative proportion of head injury was 0.61 (95% CI,

0.47-0.77). The relative proportion of head injury for the total helmet-wearing group was 0.71 (95% CI, 0.58-0.86). AIS scores of 4-6 occurred in 5 (1.9%) of approved helmet wearers and 27 (2.0%) of unhelmeted casualties. Face injury was significantly less frequent in wearers of approved helmets (24.9%) than in the unhelmeted (34.5%) with a relative proportion of 0.72 (95% CI, 0.58-0.90), a reduction of 28%. The AIS scores of wearers of approved helmets were also significantly lower. The frequency of neck injury increased in helmeted casualties (as a group) ($p < 0.05$). The AIS scores were greater for wearers of approved helmets than for non-wearers.

The AIS scores were decreased for wearers of approved helmets ($p < 0.001$), face injuries were reduced ($p < 0.01$), and extremity/ pelvic girdle injuries increased ($p < 0.001$) and the overall risk of head injuries was reduced by at least 39% and face injury by 28%. When casualties with dislodged helmets were excluded, head injuries were reduced 45% by approved helmets.

In 1991, Spaitte et al (1991) gathered data from 284 bicyclists involved in collisions with motor vehicles seen at a level-1 trauma centre. From this, only 5.2% of helmet users had an ISS>15 compared with 47.0% of non-users. The mean ISS for helmet users was 3.8 compared with 18.0 for non-users. Mortality was higher for non-users (10/168, 6.0%) than for helmet users (1/116, 0.9%; $p < 0.025$). Although patients without major head injuries (246) were analysed separately, helmet users of this group still had a much lower mean ISS (3.6 versus 12.9, $p < 0.001$) and were much less likely to have an ISS>15 (4.4% versus 32.1%, $p < 0.0001$) than were non-users. In this group, 42 of 47 patients with an ISS>15 (89.4%) were not wearing helmets.

Thomas et al. (1994) examined the risk of injury to the head and the effect of wearing helmets in bicycle accidents among children. These researches concluded that wearing a helmet reduced the risk of head injury by 63% (95% confidence interval 34% to 80%) and loss of consciousness by 86% (62% to 95%). The risk of injuries to the upper head was 2.7-fold (95% CI 1.5 to 4.9) higher among non-helmet wearers than among helmet wearers. The likelihood of loss of consciousness was 7.3-fold higher (2.6 to 20.4) among non-helmet wearers than among helmet wearers. Overall the reduction in risk among helmet wearers was 63% (34% to 80%) for upper head injuries and 86% (62% to 95%) for loss of consciousness.

Wasserman et al. (1988) interviewed 510 bicyclists over the age of 10 regarding helmet use and head injuries. Although 19% owned helmets, only 8% were wearing them when interviewed. Nearly 4% (21 bicyclists) of the bicyclists reported striking their heads in a cycling mishap during the previous 18 months. Of the 21 riders, 8 were wearing helmets at the time of the mishap. All helmets had hard shell and energy absorbing liners. Head injuries were reported by 7 of the 13 non-helmeted riders, and none of the 8 helmeted riders [odds ratio = 19.6, 95% CI = 1.2,331]

4.3. HELMET DAMAGE INVESTIGATION STUDIES

Cameron et al (1994) examined the relevance of the penetration test in the current standard AS 2.63.1-1986. They collected forty helmets sustaining impact in crashes involving cyclists who were killed or required treatment at selected Melbourne hospitals during 1991-1992. Through combining the information on the bicyclist's injuries and testing new helmets, the new helmets were compared with an older group of hard-shell helmets. The study findings were:

- The new helmets transmitted a lower level of peak acceleration to the cyclist's head;
- 33% of the major points of impact on the newly collected helmets occurred below the test line specified in AS 2.63.1-1986. With the helmets collected by the RACS during 1987-89, 63% of the major impacts occurred below the test line;
- No helmets in the RAC series had estimated impact severities equivalent to drop heights below 250 mm, while 42% of the newly collected helmets possibly did. This was attributed

to the foam-only or microshell type of the newly collected helmets being more likely to show external damage;

- 11% of the newly collected helmets and 10% of the helmets from RACS had drop heights estimated as exceeding 1500 mm, the height of the impact attenuation drop test performed by AS 2.63.1-1986.

Ching et al (1997) evaluated the relationship between helmet damage and head injuries in helmeted bicyclists. The case control studies were from 7 Seattle hospitals. 785 helmeted subjects met the criteria for inclusion and 527 helmets were used for evaluation. A high proportion of head injuries occurred in the area of the front edge of the helmet. The risk of head and brain injury increased if the helmet was significantly damaged, OR = 5.3 (95% CI 2.9, 9.9) and OR = 11.2 (95% CI 3.5, 37.9).

In a report for the Federal Office of Road Safety, Corner et al (1987) documented many aspects of head protection for pedal cyclists. Among other components of their work, they studied a total of 171 bicyclist crashes resulting in head injury. Eighteen of the injured people were wearing helmets. The study showed also that crashes involving another vehicle carry a far higher risk of head injury compared with other types of bicycle crashes, including falls from the bicycle and collisions with fixed objects. Collisions with other vehicles accounted for all of the 14 deaths included in the survey. This study also performed real crash simulations (with the helmets of the time) and found evidence of severe rotational accelerations.

Corner et al (1987) found in their study that bicycle helmets were reducing the severity of head injury, and this was particularly the case with injuries resulting from a collision with another vehicle. In these collisions, among helmeted riders 92% sustained minor injury, 0% had moderate injury, and 8% severe head injury. Among those not wearing helmets 65% sustained minor injury, 7% moderate and 28% severe (three to four times as many). Similar differences were found to exist for injuries sustained in non-collision crashes, although the differences were not as substantial.

With regard to the protecting the heads of children, the researchers showed that there is considerable flexibility in the child's skull, which will deform readily on impact. This is why a child who has suffered only a mild head impact is usually admitted to hospital for observation. The elastic deformation of the child's skull can result in quite extensive diffuse brain damage. This would indicate that children's helmets should be constructed differently from an adult's.

It was also found in this study that there was a substantial variation in the protection offered by different kinds of helmets, with the best results being found in association with helmets conforming to the then current Australian standard for bicycle helmets. As the then current Australian standard for bicycle helmets employ solid headforms for testing, the best results tend to favour stiff padding. The light "hairnet" type of helmets was associated with a higher degree of head injury.

Two groups of researchers, Hodgson (1991) and Anderson et al (1993), both investigated the effects of oblique impacts on bicycle helmets of different shell types on asphalt road surfaces.

Long et al (1986) examined the test methodology used for the penetration test in the current Australian Standard for helmet testing. Their conclusions included:

- The abolition of the existing test; and,
- The introduction of a test of the ability of a helmet to minimise skull damage through localised loading with either the Aldman anvil or the 90° edge kerb anvil.

McDermott (1986) in his paper made the following recommendations on how to improve the Australian Standard:

- The current Australian standard test line should be lowered to give increased protection;
- The Australian standard drop height of 1.5m should be increased to 2m to be consistent with the severity of impacts experienced;
- Performance tests should be modified in view of the frequency of more than one impact occurring during an accident;
- Environmental degradation tests of shells formed from materials that are susceptible to significant deterioration after manufacture should be developed;
- A helmet stability test should be developed to lessen the risk of a helmet coming off the head of the bicyclist in a crash.

McIntosh A et al (1998) collected data from hospitals and police. Only accidents in which a helmet was worn and received an impact were studied. The findings were that:

- The anterior/lateral region of the helmet was the most frequent site of impact (67%);
- The majority of non-fatal (AIS = 2+) head injuries were from helmet impacts on the anterior-lateral rim, which corresponds to the temporal/parietal region of the head;
- 25% of the impacts were at this region with 75% of these impacts producing head injuries of at least AIS = 2.

McIntosh et al (1995) examined the results of 2 earlier studies and showed that there was inadequate coverage of the temporal region. The researchers recommended that the test line could be measured directly from the Frankfort Plane. Also that the maximum acceleration was a suitable test criterion for helmet performance, but the pass/fail criteria should be reduced, so that the maximum acceleration of the head should be less than 200g, not the 300 to 400 g currently set in the standards.

Mills and Gilchrist (1990) suggested that lower density foam can only be used if the impact test standards are re-written with less emphasis on impacts with convex and pointed objects.

Rivara et al (1996) conducted a project based on a case-control design in which individuals with head or brain injuries were identified (case group) and compared to those who were involved in crashes but did not suffer head or brain injuries (control group). 88% of the 3854 subjects were recruited from 7 hospitals. The data was collected by self-reporting questionnaires, abstraction of medical records, examination of bicycle helmets and measurements of the cyclist's head. Out of the 62 bicyclists with severe brain injuries, only 24% were helmeted compared to the 57% rate of helmet use by the control group. The protective effect of the hard shell helmets for brain injuries were 73% compared to the 58% and 59% for the other types. For severe brain injuries the protective effect of the hard shell helmets was 83% compared to 70% for thin shell and 64% for no shell. In general helmets decreased the risk of head injury by 69%, brain injury by 65% and severe brain injury by 74%. Helmets did provide substantial protection against lacerations and fractures to the upper and mid face but offered little protection to the lower face. Finally the major site of helmet damage was to the rim of the frontal region.

Smith et al (1993) evaluated a group of 72 impacted bicycle helmets collected by the Head Protection Research Laboratory. Each damaged helmet underwent a thorough evaluation to determine construction detail and collision damage. Laboratory replication tests were performed to determine impact velocity and peak head form acceleration. The predominant impact location was to the front left quarter and the replication studies indicate the majority of impacts were to flat surfaces from drop heights of 1m or less (72%). Twenty two percent of the helmets sustained impacts by blunt objects and 3% due to sharp objects. The peak head-form accelerations ranged

between 38g and 179g and the mean peak acceleration was 115g (SD= \pm 36.4). Based on these results the researchers suggested that the impact requirements in current bicycle helmet standards provide adequate protection for riders involved in collisions. The mean depth of crush for all helmets examined was 3.34 mm (SD = \pm 2.31mm) for the most severe impact, and the mean measured area of impact was 43.8 cm² (SD = \pm 26cm²). Eighteen percent of the helmets had more than one impact, where the mean depth of crush for the second impact was 1.79 mm (SD = \pm 0.88mm). The mean area of linear deformation for the 2nd impact was 50.0 cm² (SD = \pm 36.2cm²).

Williams (1991) obtained injury data from 11 public hospitals in Victoria. There were 1892 bicyclists who sustained injuries, 432 were wearing helmets of which 64 had sustained impact to the helmet. The accident damage to the helmet was simulated by drop testing sample helmets from progressively greater heights until the damage observed matched that observed on the accident involved helmet.

- 63% of the impacts occurred below the test line (AS 2063.1-1986);
- Most of these impacts were concentrated on the front or temporal region (28.5%) of the riders' heads;
- The predominant form of head injury recorded was low severity concussion of AIS-1, AIS-2 and AIS-3;
- 67% of the impacts were reproduced at a drop-height less than 0.75m and 90% at a height less than 1.5m. 10% corresponded to a drop-height greater or equal to 1.5m with the highest at 2.4m. 3;
- 9.7% of the simulated impacts produced acceleration values between 0 and 100g. 90% of the simulated impacts were below 200g.
- All the serious head injuries occurred when the helmet came off or when it collapsed due to a material defect or getting stuck predominantly below the rim. Many of the helmets displayed defects in the impact-absorbing liners.

Based on these results Williams suggested the following recommendations for changes to the then current Australian Standard AS 2036.2-1990, many of which were included in AS/NZS 2036-1996 or in the current draft:

- The lowering of the test line of helmet standards;
- Performing impact tests at a drop-height of 2m;
- Reducing permissible level of radial acceleration to 300g or below;
- Performance test was required to evaluate the degree of fusion achieved in the moulding of EPS foam in helmet liners;
- Performance test for the evaluation of more than one impact during an accident;
- Helmet stability test evaluating the ability of a helmet to resist fore- and -aft motion;
- A dynamic helmet stability test reflecting the circumstances of typical accidents where the helmet becomes detached from the head;
- Environmental degradation tests of shells;
- Expanded polystyrene liners of helmets positively fixed into outer shells;
- Webbing of retention systems installed so it cannot be removed from buckles and earpieces;
- No sharp edged component of the retention system should come in contact with wearer's skin.

4.4. STUDIES OF OTHER RELEVANT ISSUES

Finnoff et al (1983) through a survey determined that the most common excuses given by people for not wearing helmets while cycling were because the bicycle helmet was “uncomfortable, annoying, it was too hot, they didn't need it or they didn't own one”. This survey was conducted at local public schools and paved bicycle trails.

Kwan and Mapstone (2003) quantified the effect of visibility aids versus no visibility aids, and of the difference in the occurrence of pedestrian and cyclist-motor vehicle collisions and injuries. The researches came to the conclusion that visibility aids do offer assistance in increasing visibility and enable drivers to determine pedestrians and cyclist earlier.

Robinson (1998) looked at the monetary cost of enforcing helmet laws and the effectiveness of helmet use. Robinson D.L. (2001) examines the statistics on helmet wear and argues that *"helmet laws and major helmet promotion campaigns are likely to prove less beneficial and less cost effective than proven road-safety measures, such as enforcement of speed limits and drink driving laws..."*. He further states that large increases in wearing with helmet laws have not resulted in any obvious change over and above existing trends. In Robinson D.L. (1996) the cost and effects of enforcing helmet laws are examined and a conclusion is drawn stating: *"the greatest effect of the helmet law was not to encourage cyclists to wear helmets, but to discourage cycling"*.

4.5. SUMMARY OF THE HELMET EFFECTIVENESS REVIEW

Henderson (1995) found that head injury is the major cause of death in 80% of fatal bicycle accidents and forms 33% of the reported injuries to bicyclists in Victoria. For children, Henderson (1995) showed that the risk of injury is reduced 63% for head injury and 86% for loss of consciousness, when a helmet is worn.

Corner et al (1987) performed a comprehensive study, which included the investigation of bicycle crashes and reconstruction of typical crashes. The study showed that most severe head injuries to bicyclist occurred in crashes with other vehicles. A major point raised regarding the protection of children was the need for a deformable headform.

The meta-analysis performed by Attewell et al (2001), which included many of the available papers, confirmed the clear benefits of helmets in terms of injury risk. The upper bounds of the 95% confidence intervals provide conservative risk reduction estimates of at least 45% for head injury, 33% for brain injury, 27% for facial injury and 29% for fatal injury. Other studies not included in the Attewell et al (1998) study have come to similar conclusions. Bjornstig et al (1992) found that at least 69 (69%) of the persons with cerebral concussion or contusion might have had the impact force reduced if they had worn a helmet.

McDermott et al (1993) found there was a reduction of 28% in facial injury for people who wore helmets compared to cyclist who didn't wear helmets. The frequency of neck injury increased in helmeted casualties (as a group) ($p < 0.05$).

With a case control study, Rivara et al (1996) found that out of the 62 bicyclists with severe brain injuries, only 24% were helmeted compared to the 57% rate of helmet use by the control group. The protective effect of the hard shell helmets for brain injuries were 73% compared to the 58% and 59% for the other types. For severe brain injuries the protective effect of the hard shell helmets was 83% compared to 70% for thin shell and 64% for no shell. In general helmets decreased the risk of head injury by 69%, brain injury by 65% and severe brain injury by 74%.

Smith et al (1993) found that for a group of 72 accident damaged helmets studied, 72% of the impacts were with flat surfaces, 22% were by blunt objects and 3% of impacts by sharp objects. Eighteen percent of the helmets in the study had more than one impact. This study also concluded that the current impact test energies were adequate.

Williams (1991) found that a high proportion of head injuries occurred in the front edge of the helmet, with 63% of the impacts occurring below the test line (AS 2063.1-1986). Most of these impacts were concentrated on the front or temporal region (28.5%) of the riders' heads. This was confirmed by Cameron et al (1994) and McIntosh et al (1998). McIntosh et al (1998) showed that the anterior/lateral region of the helmet was the most frequent site of impact (67%). The majority of non-fatal (AIS = 2+) head injuries were from helmet impacts on the anterior-lateral rim, which corresponds to the temporal/parietal region of the head.

Williams (1991) also found that all serious head injuries had occurred when the helmet came off or when it failed due to material defects or getting stuck predominantly below the rim. This was supported by Ching et al (1997) who found that the risk of head and brain injury increased if the helmet was significantly damaged in the impact, OR = 5.3(95% CI 2.9, 9.9) and OR = 11.2 (95% 3.5, 37.9) respectively. The protective effect of the hard shell helmets found by Rivara et al (1996) for brain injuries of 73% compared to the 58 % for thin shell and 59% for no shell and for severe brain injuries the protective effect of the hard shell helmets was 83% compared to 70% for thin shell and 64% for no shell.

Helmets have been proven to be effective. Based on these research findings, it is possible list attributes proven to be required for an effective helmet design. The major research study supporting the factor is appended to the finding, often the attribute will have been mentioned in several studies.

- A helmet must be worn properly to be effective, Attewell et al (2001);
- Helmets are very effective in preventing skull fracture, but less effective in preventing brain injury, Henderson (1995);
- The helmet must remain on the head during the crash, Williams (1991);
- The helmet must remain in position during the crash, Williams (1991);
- The helmet must have the maximum possible coverage of the frontal and temporal areas of the head Williams (1991), Cameron et al (1994) and McIntosh et al (1998);
- The helmet must have adequate energy attenuation characteristics, for a variety of impacted surfaces, including flat, blunt and sharp, Smith et al (1993);
- A drop energy requirement of between 1.5 and 2.2 metres appears to be adequate Williams (1991) and Smith et al (1993);
- The criteria for the energy attenuation test should be in the region of 200g, McIntosh et al (1998);
- The helmet must retain its integrity during the impact, Ching et al (1997) and Williams (1991);
- The helmet must be retained in case of a second impact, Williams (1991) and Smith et al (1993);
- A helmet with a hard shell appears to offer better protection from severe brain injuries, Rivara et al (1996);
- Severe brain injury occurs more often in impacts with other vehicles, McDermot et al (1993);
- The helmet for a young child needs to be different than for an older child or adult, Corner et al (1987).

5. COMPARISON OF HELMETS CERTIFIED TO AS/NZS 2036 AND SNELL B95 STANDARDS

5.1. INTRODUCTION

This section of the report compares the performance during testing of a sample of helmets certified to the two standards, AS/NZS 2063:1996 and Snell B95. The aim of this comparison was to assess whether there were any measurable differences in the protective capabilities of helmets to the two standards. A test program was designed based on the differing test methodologies used in the two helmet standards. The testing was designed around incorporating the helmet effectiveness issues derived from the review of helmet effectiveness in Section 4 of this report.

Based on the review of the helmet effectiveness literature, there are several aspects of the helmet performance immediately before and during a crash, which need to be considered when reviewing the adequacy of a standard. These are often grouped into three requirements, with a short explanation following, the related test from the standard is given in brackets:

1. **The helmet must be worn.** A helmet must be worn to have any effect: it must be attractive and comfortable for the wearer to be willing to wear it.
2. **The helmet must remain in place during the crash.** The retention system must be capable of keeping the helmet in place during the events immediately before (dynamic stability) and during (retention system strength) the crash.
3. **The helmet must have adequate energy attenuation.** The helmet must be capable of attenuating the impact to minimise injury. The helmet must cover the appropriate areas of the head; especially the frontal and temporal areas (test coverage). It must not disintegrate from the impact (helmet integrity) and must be capable of adequately minimising injury to the head resulting from impacts with different types of objects (energy attenuation and load distribution). The helmet must continue to remain in place on the head in case of a second impact (order of testing).

The approach used in this project was aimed at relating the field accident effectiveness data within the constraints of the test methodology already used by the two standards. To aid this process a detailed comparison of the two standards was made and this is presented in Appendix 1. To maximize the benefit of the test program complete testing to the two standards was not attempted; instead a blended version of the test methodologies used in the two standards was employed.

Two groups of bicycle helmets, one complying with AS 2063:1996 only and available on the local Australian market and the other complying with Snell B95 and available on the North American market, were selected as test samples and purchased from normal retail outlets, see the detailed helmet list in Appendix 2.

The sample helmets complying with AS/NZS 2063:1996 were chosen to represent the low to medium priced sections of the market. These helmets consisted of 42 helmets (8 or 9 samples of 5 helmet models) with AS/NZS 2063:1996 certification. For the second group, complying with Snell B95, it quickly became obvious that it was very difficult to purchase a helmet certified to this standard in North America, Pedder (2003) and Thom (2003), and impossible in Australia. Eventually 42 helmets (8 or 9 samples of 5 helmet models) were found. These consisted of 4 models with approval to Snell B95 only and one model with dual AS/NZS 2063:1996 and Snell B95 certification. On receiving delivery the helmets following shipping from the USA, an examination found that two of the helmet models were actually one design sold under different

names and so this second duplicate model was eliminated from the testing. Therefore only 4 Snell B95 models were tested.

The test sample was split so that 6 medium helmets of each model were available for testing to the requirements of AS/NZS 2063:1996 (which normally requires 4 helmets for the tests) and to Snell B95 (which requires 5). Only one local laboratory was able to test to both standards at the time, Imtest Laboratory, Christchurch, which is approved by Standards Australia for the testing of bicycle helmets. The testing carried out is described in the next section of this report.

The remaining helmets, consisting of a small, a medium and a large helmet of each model, had the test lines drawn to each standard for comparison of the headform coverage in the different sizes. Crashlab in Sydney, which is also an accredited laboratory for AS/NZS 2036:1996, did this work.

To complete the technical comparison foam sections were removed from each of these helmets and the foam density and liner thickness measured.

5.2. THE TESTING

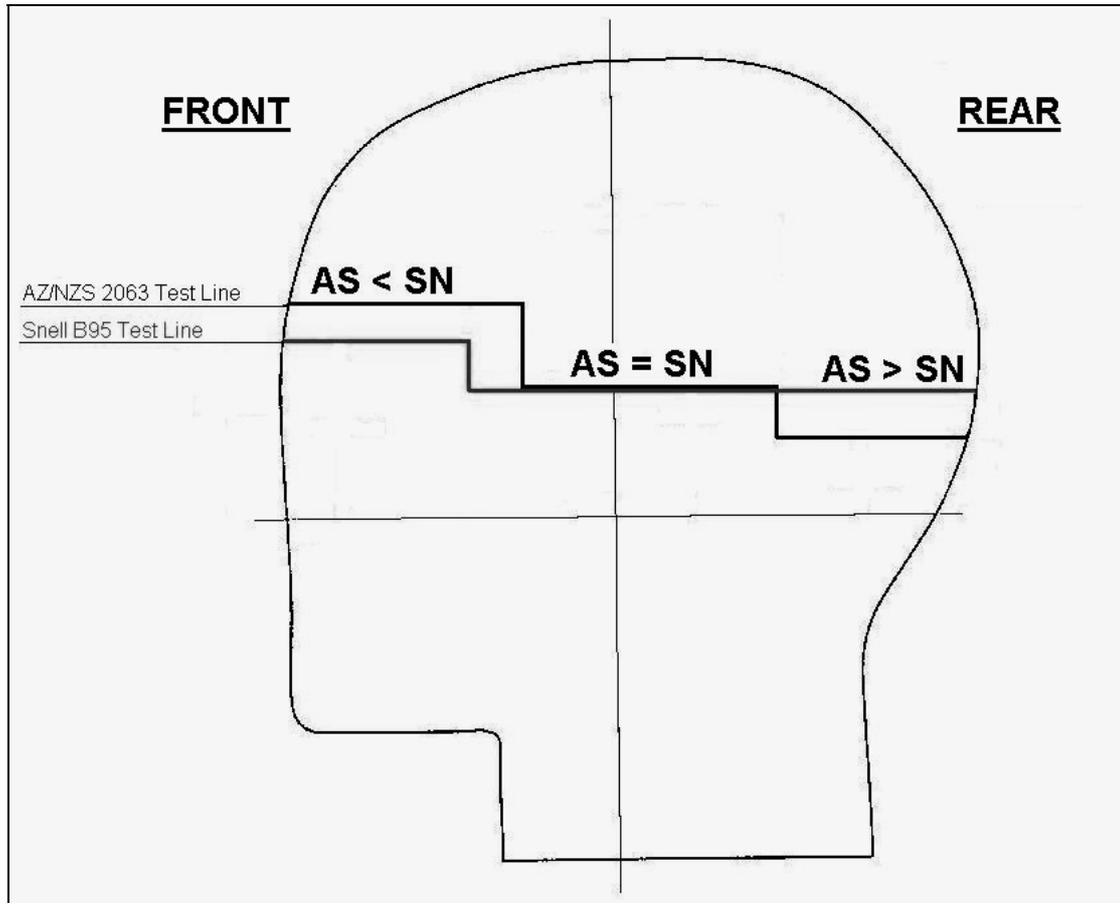
Nine different models of bicycle helmets were tested, with 6 helmets of each model submitted to the laboratory for testing to a combination of the AS/NZS2063 and Snell B95 standards.

One helmet from each model was marked with the test areas specified in AS/NZS2063 and Snell B95. The test lines were marked to the particular standard and are given in Appendix 1. These lines define the lower limit on the helmet to where impact testing is allowed. The marking up and the impact testing of the medium helmets required the use of two head forms: AS/NZS2063 used the DOT C size head form; and, Snell B95 used the size J ISO head form. The coverage given by each helmet was rated according to the scheme shown in Figure 5.1. The test line marked on a helmet is shown in Figure 5.2.

The testing to the two standards was merged for the six helmets of each model. All the tests were performed after conditioning in the ambient environment. The sequence for the tests performed on each of the helmets followed the order set by AS/NZS2063, as this was felt to be the more severe case, as any damage that occurred during the tests had the possibility of causing the helmets to fail the following retention system test. This sequence required the dynamic stability test to be performed first, followed by the impact energy attenuation/load distribution tests and finally the retention system strength test.

Where possible, all helmets certified to AS/NZS2063 were tested using the appropriate positioning index supplied by the manufacturer.

Figure 5.1. Assessing the coverage of a headform given by the test line for each standard.



Note: AS>SN AS/NZS 2036-1996 gives better coverage than SNELL B95;
 AS=SN AS/NZS 2036-1996 and SNELL B95 have equivalent coverage (to within 2mm);
 AS<SN AS/NZS 2036-1996 gives worse coverage than SNELL B95.

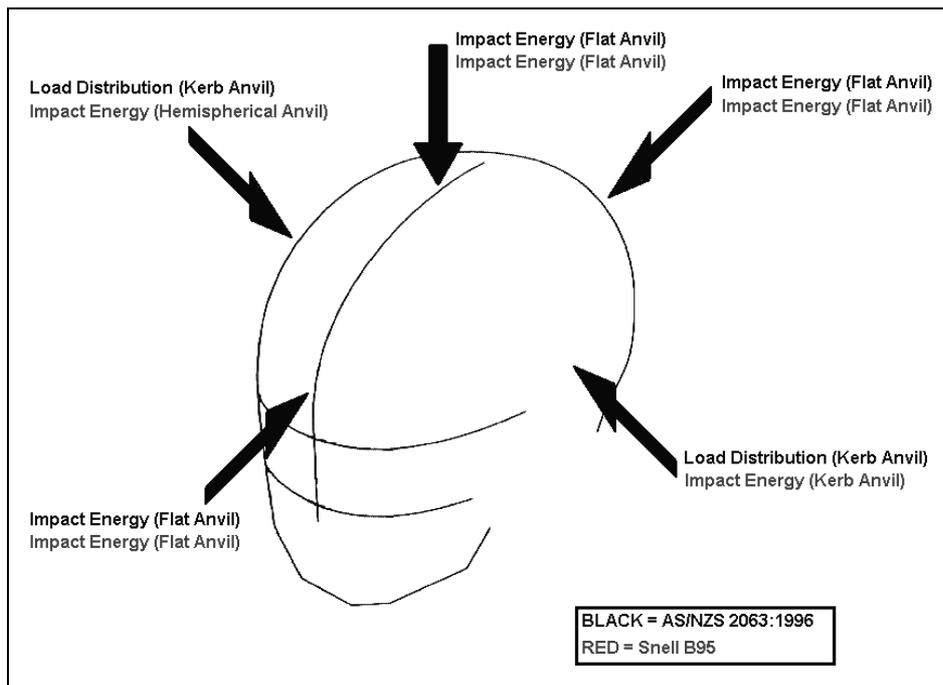
The test area used was the one that required the greatest area of protection by the helmet. Before testing photographs of each model were taken showing the marked test areas and the nominated test sites. The test sites were identical for each model and as close as was practical between models. When the test sites on the helmet were determined, the laboratory used the greater separation distance, specified in either AS/NZS2063 or Snell B95, but the location of each test site with respect to the test line was governed by AS/NZS2063.

The test sites were selected with emphasis given to flat impacts on the forehead area of the helmet. The helmets being tested to AS/NZS2063 were tested for impact energy at three test sites using the flat anvil and for load distribution at two test sites, giving five possible impact tests to be performed on each helmet. Similarly for the helmets being tested to Snell B95 impact energy requirements, this was done at three test sites using the flat anvil. The test sites used were the same as those used for AS/NZS2063. They were also to be tested at one of the two AS/NZS2063 load distribution test sites using the Snell B95 kerb anvil and at the other using the Snell B95 hemispherical anvil. The position of these sites is shown diagrammatically in Figure 5.3 and the actual positions on a helmet in Figure 5.2.

Figure 5.2. Photographs of a sample helmet (Helmets R Us Model 8) showing the test lines and the position of the five impact test site: front, top, rear and two laterals.



Figure 5.3. Diagram of a headform showing the position of the five impact test sites.



5.3. TEST RESULTS

5.3.1. Helmet Test Area

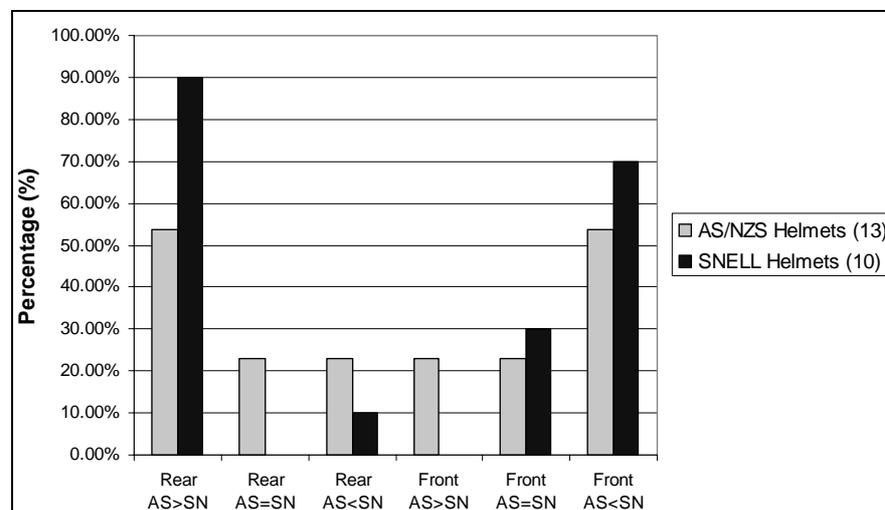
Both standards define an area of helmet for impact testing by means of a system of lines based on the basic plane of the headform, which has a reasonable fit for the helmet. For example, a medium helmet will usually fit on an ISO J headform or a DOT C headform. The positions of the test lines are defined in Appendix 1 along with diagrams of the test coverage required on the headforms. The fit of the helmet on the headform is critical for the test line position. The two varieties of headform have different shapes and size ranges and therefore are not directly equivalent in the way the two test lines are positioned for a given helmet.

AS/NZS 2036-1996 allows testing to the line. The Snell B95 standard uses a slightly different approach in that it defines a minimum coverage area for the helmet and then defines a test line, which is 15 mm above the coverage area, and testing is allowed down to this test line. The AS/NZS 2036-1996 test line is shown by the firm white line on the helmet (Helmets R Us certified to Snell B95) in Figure 6.2 and the difference between the Snell B95 coverage and test lines is shown in cross-hatching.

The helmet coverage test areas were marked up in accordance with the requirements of both standards on the 23 helmet samples. The headforms used for both marking up and testing all the medium helmets were the DOT C (for testing to AS/NZS 2036-1996) and ISO J (for testing to Snell B95). Helmets of other sizes were marked up using an appropriately fitted headform. The coverage given by a helmet depends on the headform type as well as the headform size used.

Figure 5.4 compares the test line positions on helmets certified to either standard. The AS/NZS 2036-1996 test line requires the helmet to give greater test coverage at the rear near the nape of the neck compared to the Snell B95 test line. The two standards have similar requirements for the test coverage along the side of the head and the Snell test line requires greater coverage for the front of the helmet. The results on the helmet samples reflect these requirements; the helmets tested were able to meet the test coverage required by both AS/NZS 2036-1996 and Snell B95. However, some of the AS/NZS 2036-1996 certified helmets were unlikely to meet the coverage requirement of Snell B95. These were the Bell Stryker and the Netti Strategic, both of which had a meagre coverage at the sides of the helmets. Further testing would be necessary to find out.

Figure 5.4 Comparison of the test line positions for the AS/NZS 2036-1996 and Snell B95 standards. The key to the notation is given in Figure 5.1, AS>SN indicates that coverage given on the helmet was greater for the AS/NZS2036-1996 standard.



The test areas required by the two standards were similar for all the sizes of helmet, but the area of the head covered by the Snell certified helmets was greater. The more generous coverage of the Snell B95 helmets was also indicated by the slightly higher weights on average for these helmets.

5.3.2. Helmet Stability

For each helmet model, six stability tests were performed, with three helmets tested to the AS/NZS 2063:1996 static stability test and three helmets to the Snell B95 dynamic stability test. The results of the stability tests are summarised in Table 5.1. The AS/NZS 2063:1996 static test uses a 50 N force to displace the helmet forward, while the Snell B95 uses a 4 kg test mass dropped 0.5 m. All the helmets (and hence models) tested to AS/NZS 2063:1996 passed. However, two of the AS/NZS helmets and two of the Snell helmets failed the Snell B95 test requirements for the rear impact, see Appendix 3 Test Results. These failures were due to the mechanical failure of components of the retention system, which included broken rear nape hangers, and a broken tri glide adjuster.

The Snell B95 dynamic helmet stability test is significantly more demanding of the helmet design than the AS/NZS 2063:1996 static test. The Snell test takes the retention system of the helmet near to its mechanical limits.

Table 5.1. Summary of the stability test results for AS/NZS 2063:1996 and Snell B95.

Helmets	AS/NZS Testing		Snell Testing		TOTAL		
	Passed	Failed	Passed	Failed	Passed	Failed	
AS/NZS	Front	15	0	13	0	28	0
	Rear	15	0	13	2	28	2
Snell	Front	12	0	10	0	22	0
	Rear	12	0	10	2	22	2
TOTAL	Front	27	0	23	0		
	Rear	27	0	23	4		

5.3.3. Impact Energy Attenuation Testing

Both AS/NZS 2036-1996 and Snell B95 standards require testing to establish an impact attenuation of 300g. For these tests the helmet is mounted on the appropriate size of headform and dropped in a guided fall from a specified height.

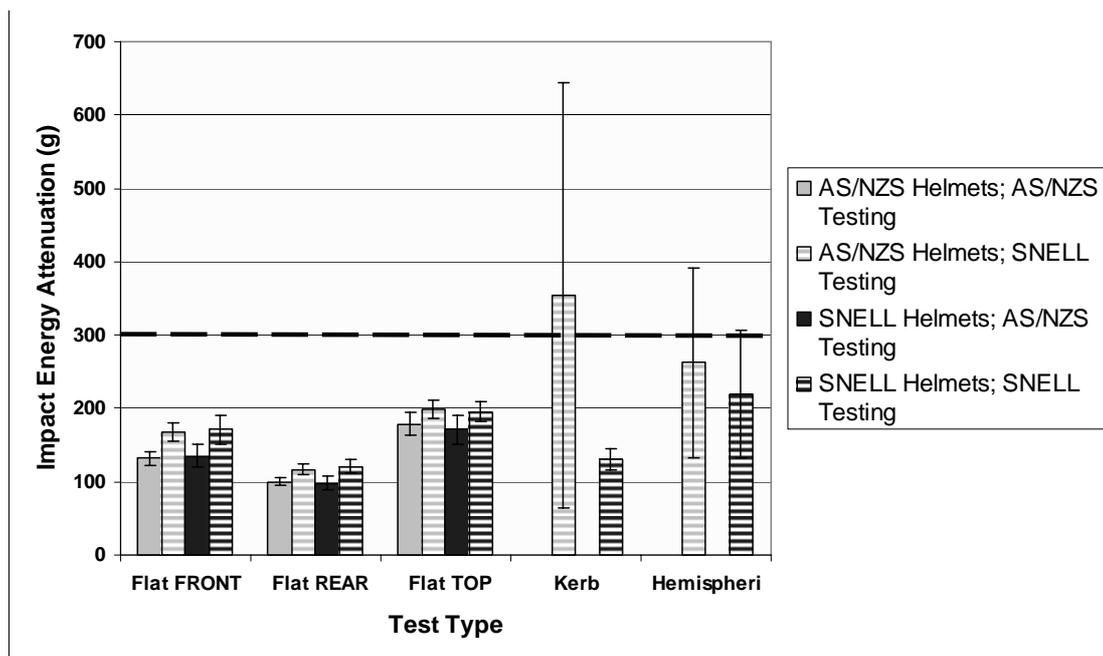
For AS/NZS 2036-1996 the drop test is made from a height of 1.5 m onto a flat anvil only. The headforms currently specified for testing are the old DOT headforms with the total drop mass variable to represent different head sizes (medium or size C is 5 kg), see Appendix A1.2. This gives a total drop energy for the impact on a medium size helmet of 73.6 J.

For Snell B95 the ISO range of headforms are used with a fixed drop mass of 5 kg. Three different anvil types are required: flat (with an impact energy of 110 J required, an equivalent drop height of 2.2 m), kerb (with an impact energy of 72 J required, an equivalent drop height of 1.5 m) and hemispherical (with an impact energy of 72 J required, an equivalent drop height of 1.5 m).

The six individual medium helmets of each of the nine models were subjected to the impact testing as outlined in the previous section of this report. A summary of the test energy attenuation results is given in Figure 6.5 for the various anvil types.

Impact energy attenuation testing using a flat anvil are included in both the AS/NZS 2036-1996 and the Snell B95 standards. Here the test was made on the front, rear, and top of the helmets. Both groups of helmets returned similar results, as seen from Figure 5.5. Further, it is clear that the higher energy of the flat anvil tests to the Snell standard generate a higher acceleration of the headform in this test for both groups of helmets, by about 25%. The safety margin built into the helmets to both standards easily deals with this increase in drop energy. Therefore the helmets to both standards offer the same impact attenuation protection in the range of impacts tested and this is confirmed by the similarity in liner densities found for the range of models tested.

Figure 5.5. Impact energy attenuation testing to AS/NZS 2036-1996 and Snell B95, with all impact sites shown and the test requirement of 300 g. AS/NZS 2036-1996 does not require testing with the kerb or hemispherical anvil.



Reviewing the responses of the individual helmet models to the flat anvil impact energy attenuation tests support this. The test results of the individual helmets to testing to the two standards for each of the impact sites are compared for the flat impacts in Figures 5.6, 5.7 and 5.8. No individual model failed the flat anvil energy attenuation requirement of 300g when tested to either standard. The two standards rate the helmet models in a similar way for these tests, but the Snell B95 testing consistently gives higher accelerations due to its higher test energy, however this was well within the margin allowed by all manufacturers.

The kerbstone and hemispherical anvil impact energy attenuation tests were only performed within the Snell B95 Standard. As is shown in Figure 5.5, for both these tests the AS/NZS 2036-

1996 approved helmets gave noticeably higher headform accelerations, with the average for these helmets exceeding the requirement of 300 g. The test variability was also significantly greater for these tests on the AS/NZS 2036-1996 approved helmets. Two of the AS/NZS 2036-1996 helmets failed these tests with the kerb and hemi anvils.

Figure 5.6 Flat anvil energy attenuation test performed on the front of the individual helmet models, on the sites shown in Figures 5.2 and 5.3.

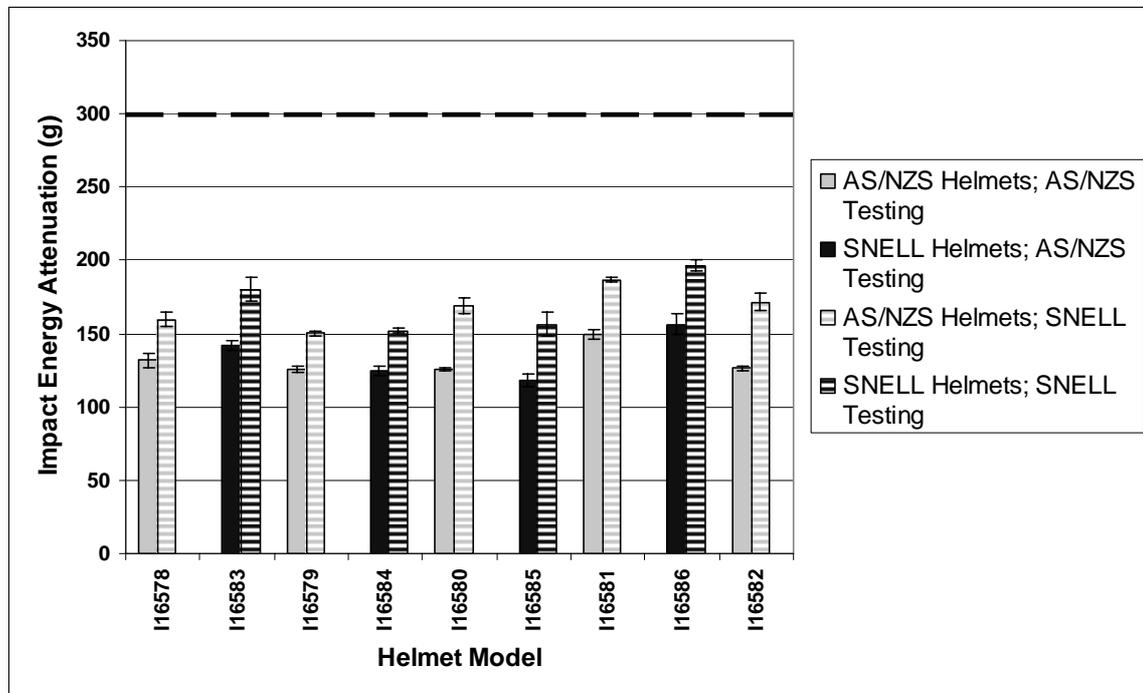


Figure 5.7 Flat anvil energy attenuation tests performed on the top of the individual helmet models, as shown in Figures 5.2 and 5.3.

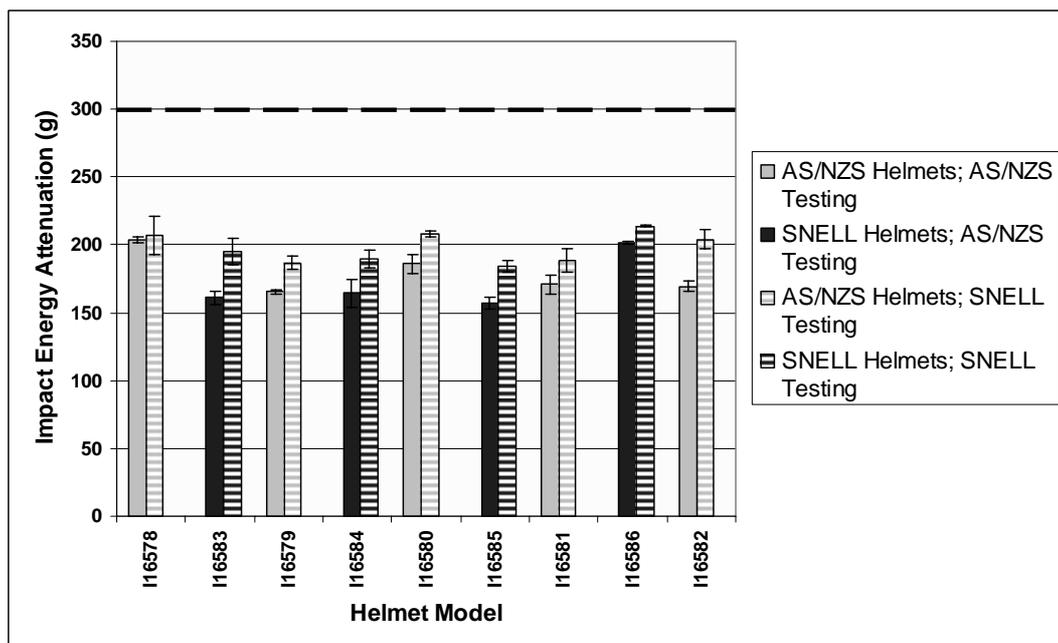
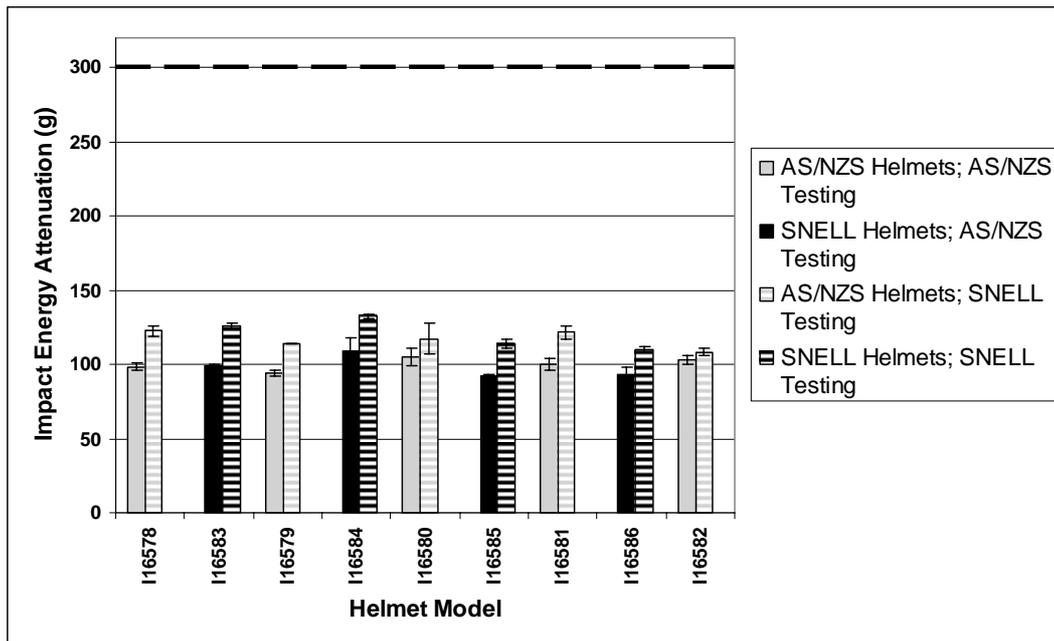


Figure 5.8 Flat anvil energy attenuation tests performed on the rear of the individual helmet models, as shown in Figures 5.2 and 5.3.



The two standards rate the helmet models in a similar way for these tests, but the Snell B95 testing consistently gave higher accelerations due to its higher test energy, however this was well within the margin allowed by the manufacturer.

The kerbstone and hemispherical anvil impact energy attenuation tests were only performed within the Snell B95 Standard. As is shown in Figure 5.5, for both these tests the AS/NZS 2036-1996 approved helmets gave noticeably higher headform accelerations, with the average for these helmets exceeding the requirement of 300g. The test variability was also significantly greater for these tests on the AS/NZS 2036-1996 approved helmets. Two of the AS/NZS 2036-1996 helmets failed these tests with the kerb and hemi anvils.

When the test results of the individual helmet models to the energy attenuation tests are compared for the kerb anvil in Figure 5.9 and for the hemispherical anvil in Figure 5.10, it can be seen that the Snell certified helmets perform better than do the Australian certified helmets. The Snell B95 standard demands a higher impact performance of the helmet. Three of the five AS/NZS 2036-1996 approved helmets failed the test with the kerb anvil and three with the hemispherical anvil. The AS/NZS 2036-1996 certified helmets also show greater test variability. The test site was possibly set too close to the edge of the test area for the AS/NZS 2036-1996 approved helmets. The two worst performing helmet models were the Bell Stryker and the Netti Strategic, which have the smallest actual coverage of the helmets tested. Of the Snell B95 approved helmets, one was marginal, the Helmets R Us Model 8, though it is possible that this helmet may have been able to pass the Snell surveillance test requirement. This is at a lower drop height of 1.3 m (or 65 J) than the certification testing, of 1.5 m (or 72 J).

Figure 6.9 The energy attenuation of individual helmet models tested with the kerb anvil to the Snell Standard.

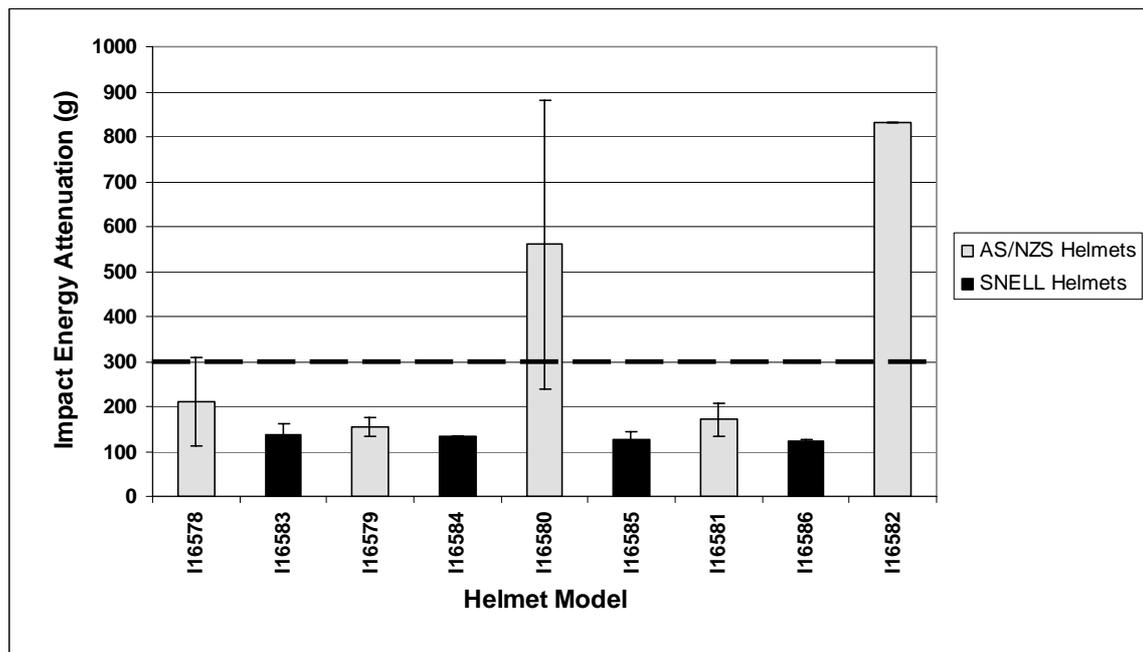
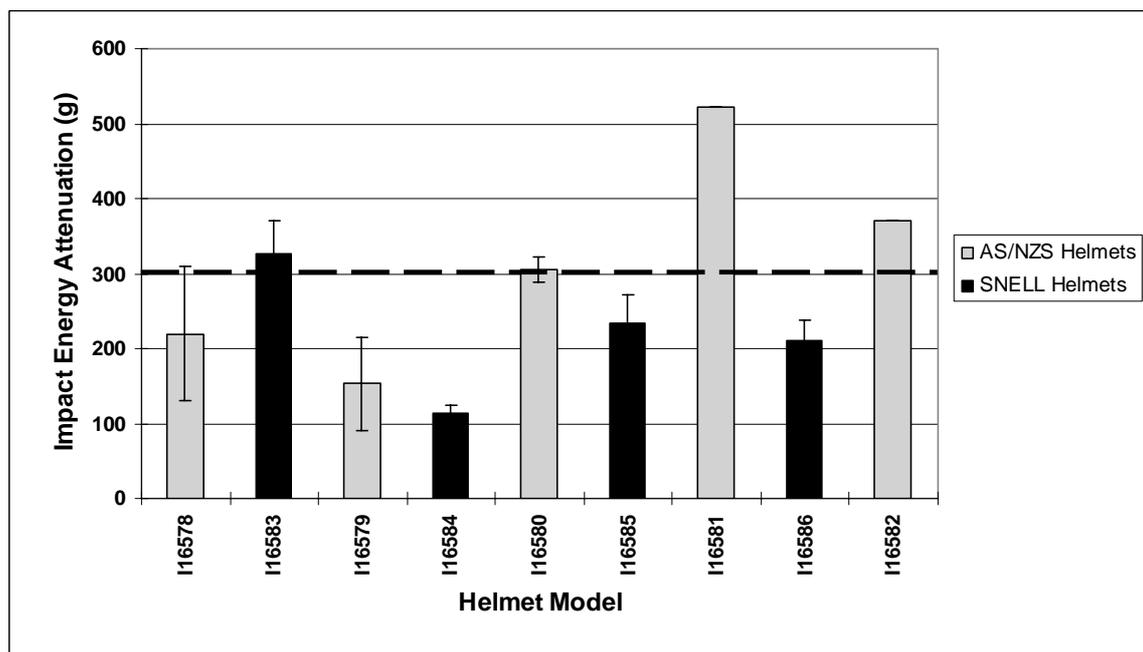


Figure 6.10 The energy attenuation of individual helmet models tested with the hemispherical anvil under Snell Standard.



For the flat anvil impact energy attenuation tests both AS/NZS 2036-1996 and the Snell B95 certified helmets were able pass the requirements for both standards. However in general the testing performed under the Snell Standard generated results that are noticeably higher than those under the AS/NZS 2036-1996. For the kerb and hemispherical anvil tests distinct differences were found with the helmets to the two standards, with several of the AS/NZS 2036-1996 certified helmets failing.

5.3.4. Load Distribution Test

The load distribution test is unique to the AS/NZS 2036-1996 standard. Figure 5.11 indicates that both the AS/NZS 2036-1996 and the Snell B95 certified helmets are all well within the limit of 500N as specified in AS/NZS 2063:1996.

When the load distribution individual helmet models test results are reviewed in Figures 5.12 and 5.13, one AS/NZS 2036-1996 certified helmet, Rosebank Ms 16, can be seen to be the cause of most of the left to right test variability. This helmet still meets the requirements of AS/NZS 2036-1996.

Figure 5.11 Load distribution test results from testing to AS/NZS 2036-1996.

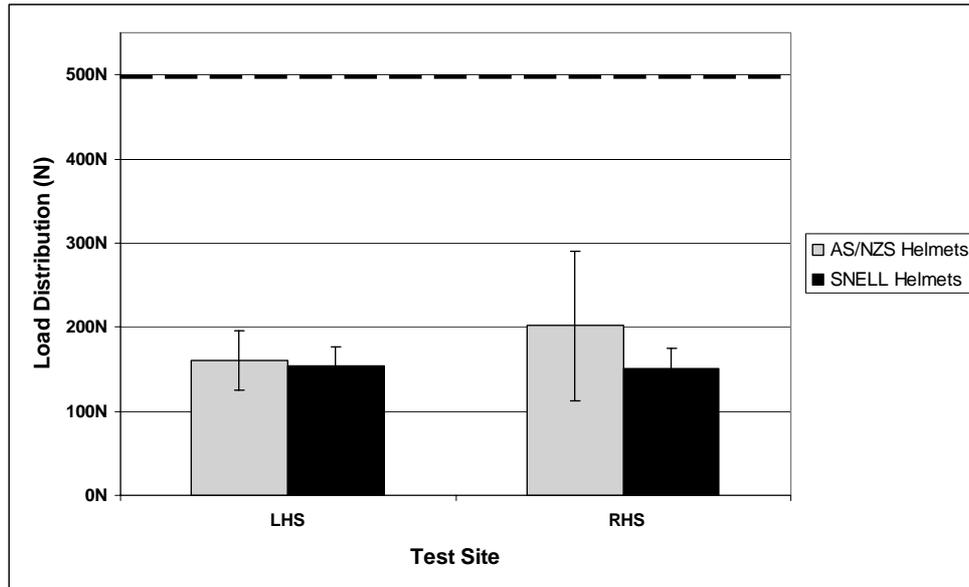


Figure 5.12 Load distribution test results (for AS/NZS 2036-1996) for left-hand side (LHS) impacts to the helmets.

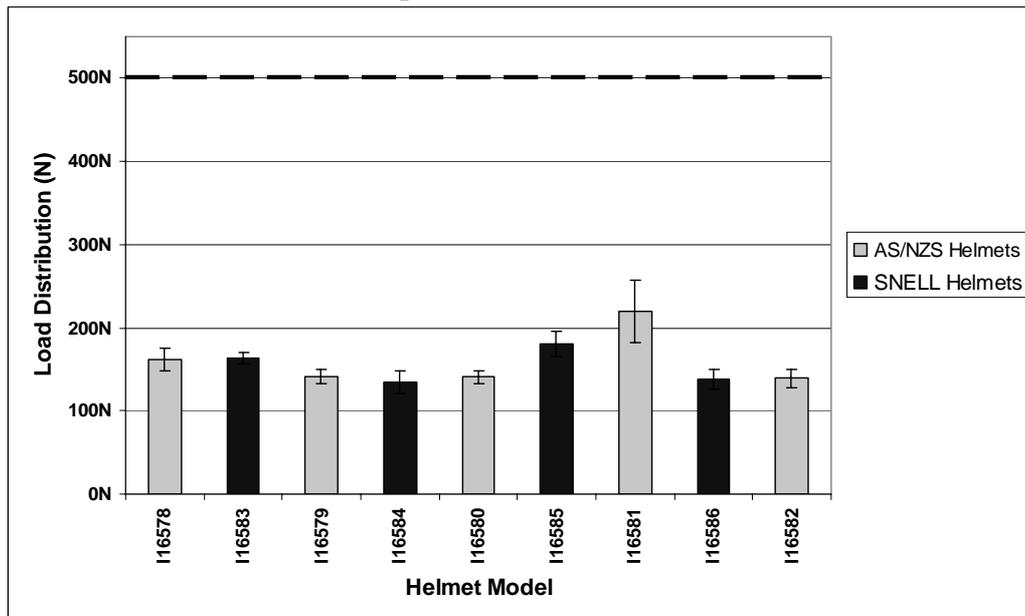
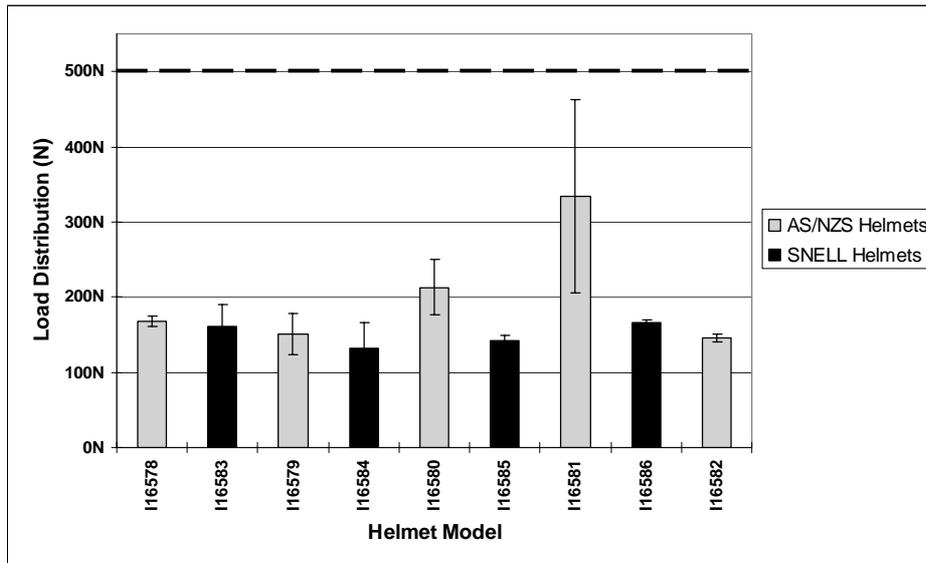


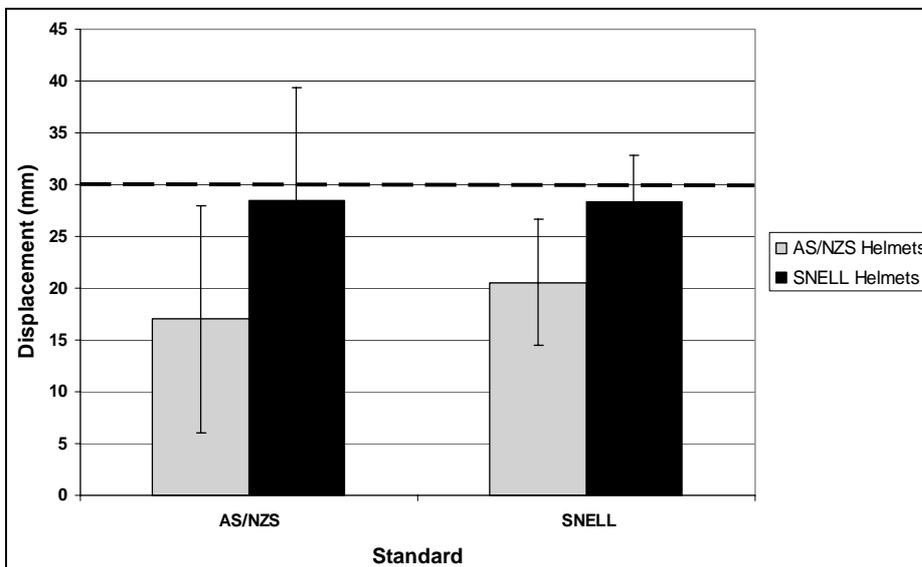
Figure 5.13 Load distribution test results (AS/NZS 2036-1996) for right-hand side (RHS) impacts to the helmets.



5.3.5. Retention System Strength

Both AS/NZS 2036-1996 and Snell B95 standards require testing of the strength of the helmet retention systems. For AS/NZS 2036-1996 the allowable displacement is 25 mm with a static load and for Snell B95 the allowable displacement is 30 mm with a dynamically applied load. The overall results are shown in Figure 5.14.

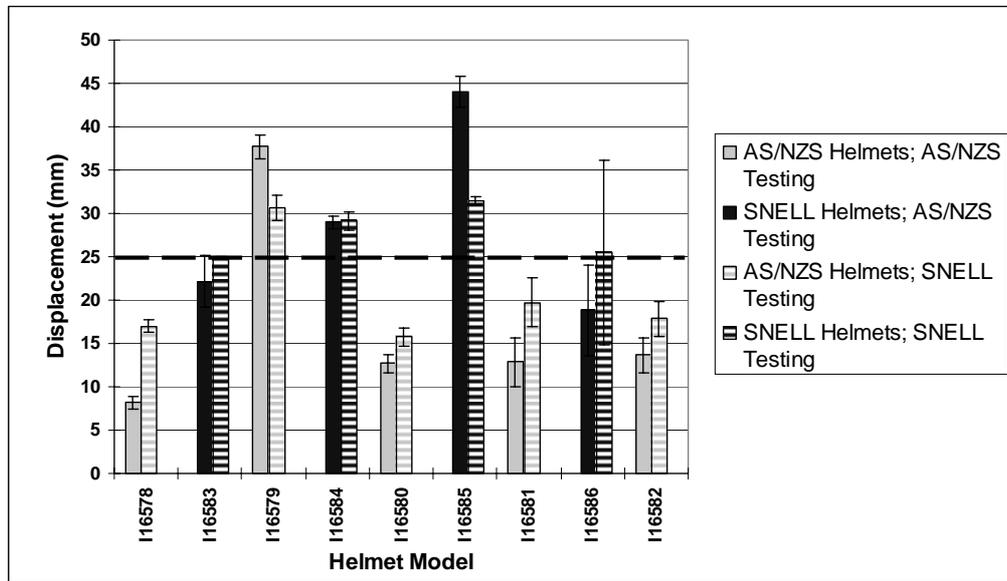
Figure 5.14 Comparison of the displacements measured for the retention system strength tests.



The retention system test results for the individual helmet models are compared in Figure 5.15. One AS/NZS 2036-1996 certified helmet failed both tests, one Snell B95 certified helmet failed the AS/NZS 2036-1996 test, another the Snell B95 tests and one failed both standards. Based on these failures for both test situations, the AS/NZS 2036-1996 certified helmets appear to have greater retention strength in comparison to the Snell B95 helmets. In addition, the average

dynamic displacement for the Snell B95 certified helmets was close to exceeding the maximum limit of both AS/NZS 2036-1996 and Snell B95 standards. This may partly have been due to the use of the AS/NZS 2036-1996 test order. The damage to the helmet due to the earlier impact tests sometimes allows more deformation of the retention system.

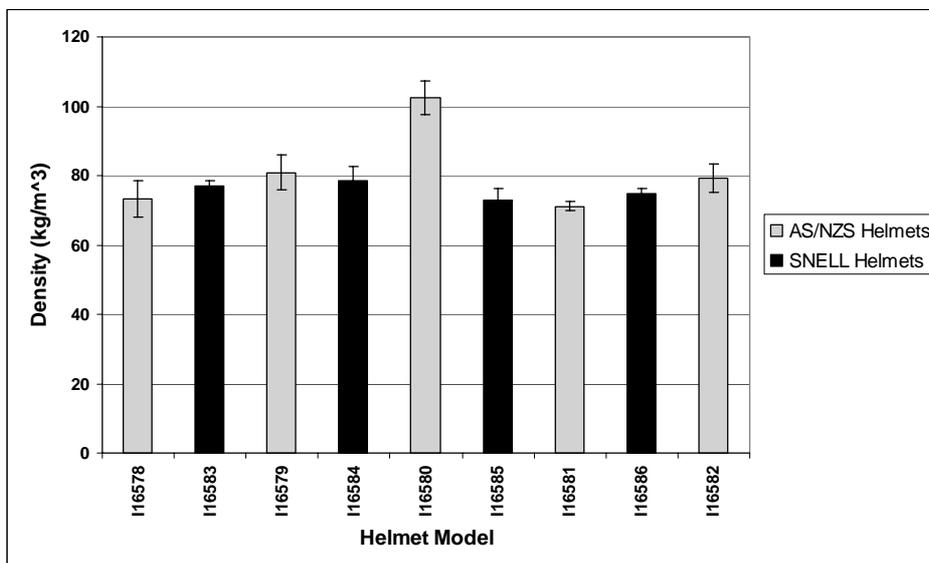
Figure 5.15 *Measured displacements for individual helmet models for the retention system strength tests.*



5.3.6. Helmet Foam Density and Mass

Several extra measurements were made on the 23 individual helmets, see Figure 6.16. The foam density was measured and for the helmet models averaged across the available sizes was in the range between 70 to 80 kg/m³. The one exception was the Bell Stryker (#16580), which was significantly denser at 103.5 kg/m³. This helmet was the most expensive sampled and is the most

Figure 6.16 *Measured liner foam density of helmet models averaged across the available sizes.*



modern in design. It therefore has the greater ventilation area of many of the newer designs and the higher density is a clear indication of how this is achieved. More ventilation space leaves less volume available for the foam and so requires higher foam density to meet the energy attenuation requirements. The higher density foam has higher localised pressure during an impact test. It is this trend in helmet design, which has provoked the criticism of the load distribution test. There were no indications of any trends in the foam density due to helmet size or certification standard.

The measured masses of the helmets are given in Table 5.2 as averages for the helmets by size and by standard. The AS/NZS 2036-1996 certified helmets are all consistently lighter across the whole size range than the Snell B95 certified helmets. This is a direct measure of the larger area of coverage of the head given by the Snell standard, as the density of the foam was similar for all the helmets tested. The high density foam in the two sizes of Bell Stryker (SM = 272 gms and ML = 298 gms) made these helmets heavy for AS/NZS 2036 certified helmets.

Table 6.2 *The average mass of the helmets by size and by standard.*

Size	Helmet Mass (g)	
	AS/NZS	Snell
Certifying Standard	AS/NZS	Snell
Small	212	240.5
Medium	256.4	266.5
Large	256.75	271
All	239.8	263.1

6. DISCUSSION

The review of the helmet effectiveness literature reviewed in Section 4, indicated that there are several aspects of the helmet performance immediately before and during a crash, which need to be considered when reviewing the adequacy of a standard. These are often grouped into three requirements, with a short explanation following, the related test from the standard is given in brackets:

1 The helmet must be worn. A helmet must be worn to have any effect must be attractive and comfortable for the wearer to be willing to wear it. There are many factors involved in this and only some of them are related to the helmet design. Some design features of the helmets, which do have influence here, are not included in the bicycle helmet standard at present, such as fit and comfort, effective ventilation and mass, even though such standard tests do exist.

2. The helmet must remain in place during the crash. The retention system must be capable of keeping the helmet in place during the events immediately before (dynamic stability) and during (retention system strength) the crash.

3. The helmet must have adequate energy attenuation. The helmet must be capable of attenuating the impact to minimise injury. The helmet must cover the appropriate areas of the head; especially the frontal and temporal areas (test coverage). It must be capable of adequately minimising injury to the head resulting from impacts with different types of objects (energy attenuation and load distribution) and must not disintegrate from the impact (helmet integrity). The helmet must continue to remain in place on the head in case of a second impact (order of testing).

We can combine the test data from these helmets to assess the relative worth based on the needs proposed by the helmet effectiveness research summarised earlier. This comparison is presented in Table 6.1.

Table 6.1 Comparison based on the test requirements and methodologies of the two bicycle helmet standards as related to field accident requirements and demonstrated by the helmet testing for this project.

Standard Test Methodology		AS/NZS 2036-1996	Snell B95
1. The helmet must be worn.	Mass	✓	NA
	Ventilation	NA	NA
	Comfort	NA	NA
	Style	NA	NA
2. The helmet must remain in place during and after the crash.	Stability Test	✓	✓ ✓
	Retention System Strength	✓ ✓	✓
	Order Of Testing	✓	NA
3. The helmet must have adequate energy attenuation.	Coverage	✓	✓ ✓
	Energy Attenuation	✓	✓ ✓
	Load Distribution	✓	NA
	Helmet Integrity	✓	✓

NA - Not available in the standard.

✓ - Required by the standard.

✓ ✓ - Most stringent requirement.

The requirements of the Snell B95 standard in the critical areas of helmet coverage, stability and energy attenuation are more stringent than for AS/NZS 2036-1996 and hence potentially able to

produce a helmet more protective of the user. The test coverage of the two standards is equivalent, but the overall coverage requirement of Snell B95 gives the head of the user more coverage, especially over the temporal region. The dynamic stability test for Snell B95 is a significantly better and more severe than the static stability test used in AS/NZS 2036-1996. The energy attenuation requirements do not seem to be achieved by increasing the foam density in the helmets. This being one way for the manufacturer to improve the helmet response for the higher severity impacts in the Snell B95 standard. Higher foam densities have the possibility of worsening of the likelihood of brain injury in low severity impacts. The retention system strength test used in AS/NZS 2036-1996 demands a stronger retention system than does the Snell B95 standard. The order of testing used by AS/NZS 2036-1996 is more demanding of the design of the retention system of a helmet as well. This sample of helmets to both standards was all able to meet the requirements of the AS/NZS 2036-1996 load distribution test. This is not necessarily true for all helmets to the Snell B95 standard. Therefore, based on this comparison the Snell B95 standard test requirements are capable of producing a slightly more protective helmet.

Consistency of the helmet test responses is the area where a good quality assurance program for the helmet is necessary. In this test series only a limited number of helmets were tested to an abbreviated set of tests for each standard, it is not possible to look at overall consistency. It is of some interest though to look at the number of failures to meet the test requirements that occurred within this limited sample.

The sample of six AS/NZS 2036-1996 certified helmet models when tested to AS/NZS 2036-1996 requirements had no failures after the Star SB 107 helmet was removed from the comparison. Where the 4 Snell B95 certified helmet models, when tested to Snell B95 certification requirements had 8 failures, made up of 2 failures to meet the stability requirements (2 helmet models), 4 to meet the retention system strength requirements (2 helmet models) and 2 to meet the hemispherical anvil energy attenuation test (one helmet model). The failures occurred to three out of the four helmet models tested. This gives a failure rate for the Snell B95 certified helmets of 75 % by model and 8.2 % by test. The Snell B95 certified helmets in the sample lacked consistent test performance.

This lack of consistency during the testing is an indication that this sample of B95 certified helmets has been the subject of an inadequate level of quality assurance during production. It also implies that Snell B95 certified helmets are less capable of giving a defined level of protection to the user than AS/NZS 2036-1996, regardless of the stringency of the test requirements.

The US experience of enforcing various levels of quality assurance on the helmets on the market is worth reiteration as it gives a historical perspective on the issue of a “reasonable” level of quality assurance for a product such as a helmet. The initial bicycle helmet standard, the ANSI Z90.4 standard, was entirely self administered by the manufacturer. User groups began to suggest in the mid 1980s that it was necessary to supplement the ANSI certification with Snell B 85 certification as well. This version of the Snell standard had the random sample aftermarket surveillance in place and so was seen to produce a more consistent performance from the helmets on the market. The industry took up the ASTM standard in 1994, and dropped Snell as a certification agency using SEI instead. SEI carried out an independent but simple quality assurance scheme, including factory inspection and yearly re-certification. This was in turn superseded in 1999 for bicycle helmets by the current CPSC regulation which demands a “reasonable” test program with batch testing, but is still self administered by the manufacturer. The recall record for this standard has been poor with regular recalls occurring, even though the CPSC is criticised for being too lenient with failures of helmets to comply with the regulation.

The current Australian certification system has a demonstrated ability to ensure bicycle helmets which perform to an acceptable, consistent level of safety are supplied to the user. It is able to do this as a result of the quality assurance system which is part of the certification process.

7. SUMMARY

Changes have been made to the Trade Practices Act intended to legalise the sale in Australia of bicycle helmets meeting the American Snell B95 Standard. These changes have been made as part of the regular review of the mandatory consumer product safety standard for pedal cyclists under the Trade Practices Act 1974, as the current regulation, which was based on AS 2063.2-1990, had become outdated, Department of the Treasury (1999). The State and Territory road authorities have not accepted the changes. Specifically, the road authorities have expressed concern regarding two areas:

- The lack of a quality assurance process for Snell-certified helmets on the Australian market; and,
- Whether the technical differences between the Snell B95 and AS/NZS2063 standards reflect significant differences in the level of safety provided by helmets to these two standards.

Snell claims to have the premium helmet standard. This comparison indicates that the test requirements of the Snell B95 standard are slightly more stringent than those in AS/NZS 2036-1996.

A sample of six AS/NZS 2036-1996 certified helmet models were purchased and tested to AS/NZS 2036-1996 requirements. One of these models was found to not be officially certified to AS/NZS 2036-1996. There were no failures during testing of the AS/NZS 2036-1996 certified helmets.

The sample of four Snell B95 certified helmet models were tested to Snell B95 certification requirements. The group had 8 failures, made up of 2 failures to meet the stability requirements (2 helmet models), 4 to meet the retention system strength requirements (2 helmet models) and 2 to meet the hemispherical anvil energy attenuation test (one helmet model). The failures occurred to three out of the four helmet models tested. This gives a failure rate for the Snell B96 certified helmets of 75 % by model and 8.2 % by test. Two of these failures were significant and to one helmet model (the energy attenuation requirements), the other failures are more minor but they were still failures to meet the requirements of two safety related tests.

The testing showed a lack of consistency in the ability of the Snell B95 certified helmets to meet the requirements of the Snell B95 standard. This lack of consistency is a clear indication of inadequate quality assurance during the manufacturing process. On the basis of this lack of consistent performance when tested, the Snell B95 certified helmets are not capable of giving the level of protection expected from the requirements of the standard. At least eight percent of the sample of the Snell B95 certified bicycle helmets tested for this project would fail to protect the user to the level expected.

APPENDIX 1 - COMPARISON OF THE TWO STANDARDS

A1.1 TEST METHOD

Standard	Helmet Preparation	Helmet Mass	Headforms	Test Sites
1996 Australian/ New Zealand Standard Pedal cycle helmets AS/NZS 2063:1996	<p>Four pairs of helmets of the same size and representative of production lots, each pair of are subjected to a different conditioning procedure.</p> <p>AMBIENT TEMPERATURE. 18C to 25C for 16 to 30 hours. LOW TEMPERATURE. -5C ±2C for 16 to 30 hours. HIGH TEMPERATURE. 50C ±2C for 16 to 30 hours in a circulating air oven. WATER IMMERSION. 18C to 25C for 16 to 30 hours.</p> <p>Each helmet would be subjected to impact energy attenuation or load distribution, and then retension system.</p>	<p>Head form size and MAXIMUM helmet mass (g):</p> <p>AA 300g A 300g E 400g J 500g M 600g O 700g</p> <p>The actual mass of the helmet shall not differ from the nominal mass ±10%.</p>		SEE FIGURE 1-6
2002 Draft for Public Comment Australian/ New Zealand Standard - Pedal cycle helmets (DR 02473) [Revision of AS/NZS 2063:1996]	<p>4 pairs (8 helmets) of helmets of the same size and representative of production lots, each pair of are subjected to a different conditioning procedure.</p> <p>AMBIENT TEMPERATURE. 18C to 25C for 16 to 30 hours. LOW TEMPERATURE. -5C ±2C for 16 to 30 hours. HIGH TEMPERATURE. 50C ±2C for 16 to 30 hours in a circulating air oven. WATER IMMERSION. 18C to 25C for 16 to 30 hours.</p> <p>Each helmet would be subjected to impact energy attenuation or load distribution, then dynamic strength test.</p>	<p>Head form size and MAXIMUM helmet mass (g):</p> <p>AA 300g A 300g E 400g J 500g M 600g O 700g</p> <p>The actual mass of the helmet shall not differ from the nominal mass by more than 10%.</p>		SEE FIGURE 1-6
1995 Standard For Protective Headgear For Use In Bicycling (Snell B95)	<p>6 helmets of the same size are to be tested after conditioning.</p> <p>BAROMETRIC PRESSURE. 75 to 110 kPa for at least 4 hours. LABORATORY TEMPERATURE. 17C to 27C for at least 4 hours. RELATIVE HUMIDITY. 20% to 80% for at least 4 hours.</p> <p>COLD. -20 C ±2 C between 4 and 24 hours. HEAT. 50 C ±2 C between 4 and 24 hours. WET. Immersed crown down in water at 17C to 27C to a crown depth of 305 mm ±25 mm between 4 and 24 hours.</p> <p>All testing shall begin within 2 minutes from conditioning.</p> <p>Helmet 1: Ambient temp and humidity. Helmet 2-4: Conditioned to hot, cold and wet respectively. Helmet 5: Conditioned to hot, cold or wet according to the best judgement.</p> <p>Helmet 1: Subjected to positional stability test, then impact management test. Helmet 2-5: Subjected to dynamic test of retension system, then to impact management test.</p>			<p>A test line is drawn 15 mm from the closest point on the boundary.</p> <p>If the extent of protection lies below edge of the helmet, the test line will be drawn 15 mm from an imaginary boundary.</p> <p>SEE FIGURE 1-6</p>
Child Helmet Addendum - For Children Four Years of Age and Younger (Applies to B90A, B95 & B95A)			<p>Helmets shall be placed on 'E' headform. If helmet is too small, use ISO 'A'.</p> <p>The helmet shall be held in place by an applied force of 50 newtons (11.25 lbs)</p> <p>Helmet positioned is adjusted to the manufacturer's specified HPI.</p>	<p>A test line is marked 15 mm from the closest point on the boundary.</p> <p>If there is insufficient material below the test line to withstand impact testing without endangering the test equipment, the helmet may be rejected.</p> <p>SEE FIGURE 1-6</p>

Standard	Peripheral Vision	Helmet Stability - Static	Helmet Stability - Dynamic	Retention System - Design	Retention Strength - Static
1996 Australian/ New Zealand Standard Pedal cycle helmets AS/NZS 2063:1996	<p>At basic plane, peripheral vision clearance > 105° on each side of the mid-sagittal plane.</p> <p>Brow opening and the outer peak > 25 mm above basic plane.</p>	<p>Using a force of 50 ±0.5 N for 15 s to 30 s, the helmet shall neither completely expose nor obscure the test band.</p> <p>Helmets shall be tested on the Amod or Jmod headforms.</p> <p>Tested in accordance with AS/NZS 2512.7.1.</p>		<p>Retaining strap shall be designed to be worn under the jaw.</p> <p>The retaining system shall not include a chincup.</p> <p>Any contact of the throat on the underside of the wearer's jaw shall be not less than 12 mm wide.</p> <p>Tension on straps between all fixing points when the retaining strap is properly fastened</p>	<p>A preliminary force of 225 ±5 N is applied for 30 s and then an additional force of 500 ±5 N is applied for 120 s.</p> <p>The retention system shall not separate.</p> <p>The elongation between the preliminary load and the test load < 25 mm.</p>
2002 Draft for Public Comment Australian/ New Zealand Standard - Pedal cycle helmets (DR 02473) [Revision of AS/NZS 2063:1996]	<p>At basic plane, peripheral vision clearance > 105° on each side of the mid-sagittal plane.</p> <p>Brow opening and the outer peak > 25 mm above basic plane.</p>	<p>Using a force of 50 ±0.5 N for 15 s to 30 s, the helmet shall neither completely expose or obscure the test band.</p> <p>Helmets shall be tested on the Amod or Jmod headforms.</p> <p>Tested in accordance with AS/NZS 2512.7.1.</p>	<p>Using a drop height of 175 -0, +5 mm to pull the helmet forward, the helmet shall not come off the headform.</p> <p>Tested in accordance with AS/NZS 2512.7.2.</p>	<p>Retaining strap is to be worn under the lower jaw;</p> <p>Tension on straps between all fixing points when the retaining strap is properly fastened</p> <p>Any contact of the throat on the underside of the wearer's jaw shall be not less than 15 mm wide.</p>	
1995 Standard For Protective Headgear For Use In Bicycling (Snell B95)	<p>A force of 50 newtons holds the helmet in place.</p> <p>At basic plane, peripheral vision clearance > 110° on each side of the mid-sagittal plane.</p> <p>This range must be unobstructed below the plane that intersects the headform at the S2 plane and that is inclined 40 upward.</p>		<p>The helmet is tested on the smallest headform.</p> <p>The headform stand has its vertical axis pointed downwards at an angle of 135.</p> <p>The helmet is tested for both frontal and rear impact.</p> <p>An inertial hammer shall enable a 4.0 kg ± 50 g mass to be dropped through a 0.6 m guided fall in order to deliver an abrupt shock load to the headgear.</p> <p>The inertial hammer mass is no more than 5.0 kg including the 4.0 kg shock mass.</p> <p>The helmet may be shifted but must remain on the headform.</p>	<p>Quick release buckles shall not be able to be released inadvertently.</p>	
Child Helmet Addendum - For Children Four Years of Age and Younger (Applies to B90A, B95 & B95A)	<p>The peripheral visual clearance is the solid angle bounded by the reference plane, the CC2 plane and 2 more planes perpendicular to reference plane.</p> <p>The 2 planes form an angle of 110 with the longitudinal plane on each side.</p>				

Standard	Retention Strength - Dynamic	Impact Energy Attenuation	Drop Assembly	Load Distribution	Internal Projections	External Projections
1996 Australian/ New Zealand Standard Pedal cycle helmets AS/NZS 2063:1996		Helmets tested at 4 sites above the test line. Test sites > 1/6 max helmet circumference apart. Impact tests on 3 different anvils: 1) FLAT STEEL ANVIL: Diameter = 127mm. 2) HEMISPHERICAL STEEL ANVIL: Radius = 48mm. 3) STEEL V-ANVIL: Angle between 2 flat face = 90 ±1degrees; Height = 85 ±5mm; Hardness = 60 Rockwell; Finish no coarser than 25 um. Using a flat anvil only and a free-fall height of 1500 +30, -5 mm: (a) Headform acceleration < 300 g peak. (b) Cumulative duration of acceleration < 3.0 ms for acc > 200 g (c) Cumulative duration of acceleration < 6.0 ms for acc > 150 g	Combined mass of drop assembly + headform (in kg): AA 2.5 ±0.05 ISO A 3.1 ±0.05 ISO E 4.1 ±0.05 ISO J 4.7 ±0.05 ISO M 5.6 ±0.05 ISO O 6.1 ±0.05 The old headforms are still being used: DOT A 3.5 kg DOT B 4.0 kg DOT C 5.0 kg DOT D 6.0 kg	Helmets tested at 4 sites above the test line. Distance (surface of helmet) between any 2 test sites > 1/5 internal helmet circumference (at the nominal AA' line). Using fall height of 1000 +15, -5 mm: (a) Load measured by force transducer < 500 N over 100 mm2 . (b) The anvil shall not contact the surface of the headform. Tested in accordance with AS/NZS 2512.9	No internal projections likely to cause injury to the wearer in case of an accident.	Rigid projections and irregularities < 5 mm.
2002 Draft for Public Comment Australian/ New Zealand Standard - Pedal cycle helmets (DR 02473) [Revision of AS/NZS 2063:1996]	Drop weight of 10.0 ±0.1kg. 2 metal rollers (Diam: 12.7 ±1.0mm; Center-to-center dist: 75.0 ±1.5mm) used to represent bone structure of lower jaw. The mass of the guide bar assembly shall be 7.0 ±0.1kg. The guide bar diameter must be < 32mm. Drop height of 250 -0, +5 mm. Measure permanent displacement of the chin strap stirrup 30s after drop. Dynamic displacement must be < 30 mm.	Helmets tested at 4 sites above the test line. Distance (surface of helmet) between any 2 test sites > 1/5 internal helmet circumference (at the nominal AA' line). Impact tests on 3 different anvils: 1) FLAT STEEL ANVIL: Diameter = 127mm. 2) HEMISPHERICAL STEEL ANVIL: Radius = 48mm. 3) STEEL V-ANVIL: Angle between 2 flat face = 90 ±1degrees; Height = 85 ±5mm; Hardness = 60 Rockwell; Finish no coarser than 25 um. Using a flat anvil only and a free-fall height of 1500 +30, -5 mm: (a) Headform acceleration < 250 g peak. (b) Cumulative duration of acceleration < 3.0 ms for acc > 200 g (c) Cumulative duration of acceleration < 6.0 ms for acc > 150 g	Combined mass of drop assembly + headform (kg): AA 2.5 ±0.05 kg A 3.1 ±0.05 kg E 4.1 ±0.05 kg J 4.7 ±0.05 kg M 5.6 ±0.05 kg O 6.1 ±0.05 kg	Helmets tested at 4 sites above the test line. Distance (surface of helmet) between any 2 test sites > 1/5 internal helmet circumference (at the nominal AA' line). Using fall height of 1000 +15, -5 mm: (a) Load measured by force transducer < 350 N over 100 mm2 . (b) The anvil shall not contact the surface of the headform. Tested in accordance with AS/NZS 2512.9	Rigid projections and irregularities on the internal surface < 5 mm in height. The helmet should have no internal projections or irregularities likely to cause injury to the wearer in an accident.	Rigid projections and irregularities < 5 mm. A fairing becomes a projection when the included angle it makes with the external surface of the helmet > 45 degrees.
1995 Standard For Protective Headgear For Use In Bicycling (Snell B95)	The device will be given a mechanical pre-load followed by a dynamic loading. The retention system fails if: (a) It cannot support the mechanical load. (b) The max deflection during dynamic load > 30 mm. (c) It cannot be easily and quickly unfastened after testing. The chinstrap loading device shall consist a simulated jaw (2 rollers, 12.7 mm ± 0.5 mm in diameter each, separated by 76 mm ± 0.5 mm on center). The mass of this device including the 4 Kg drop mass shall not exceed 11.0 kg. A 4 kg mass is dropped in a vertical guided fall of 60 cm.	Helmets tested at no more than 4 sites above the test line. Test impact site > 120 mm to each other. The helmeted headform is dropped in guided falls onto specified test anvils FLAT ANVIL. Impact energy = 110 J for certification test and 100 J for other test. This represents a 2.2+ m drop of a 5 kg headform and supporting assembly. HEMISPHERICAL & KERBSTONE ANVIL. Impact energy = 72 J for certification test and 65 J for other test. This represents a 1.3+ m drop of a 5 kg headform and supporting assembly. Impact energy must be < 3% of energy specified. Peak acceleration < 300 g.	The total mass of the headform/support assembly shall be 5.0 ±0.1 kg.		No fixture on the inner surface projecting > 2 mm.	Any projection > 5 mm must readily break away.
Child Helmet Addendum - For Children Four Years of Age and Younger (Applies to B90A, B95 & B95A)						

A1.2 THE TEST LINES

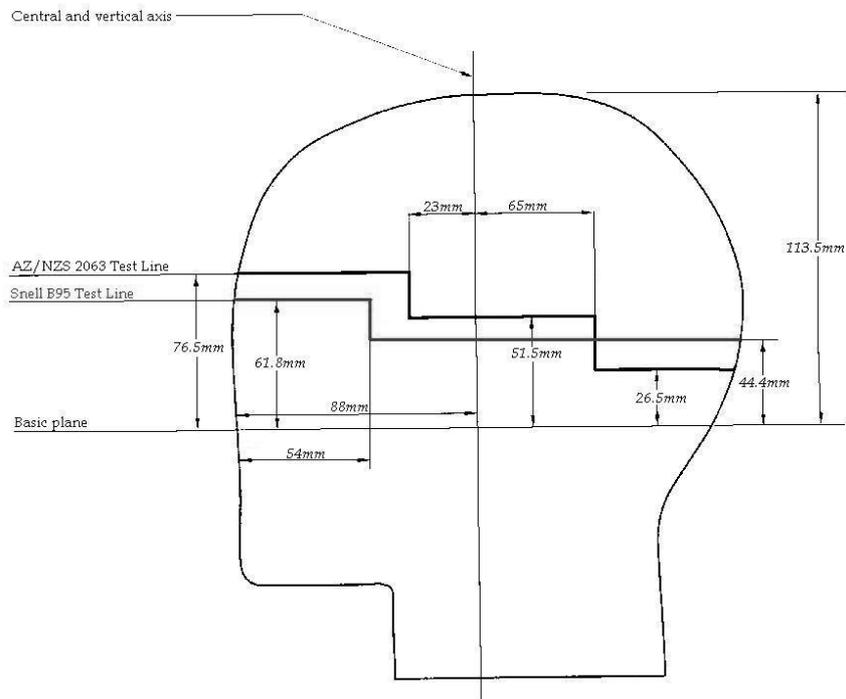


Figure 7.1. Test Line Headform A

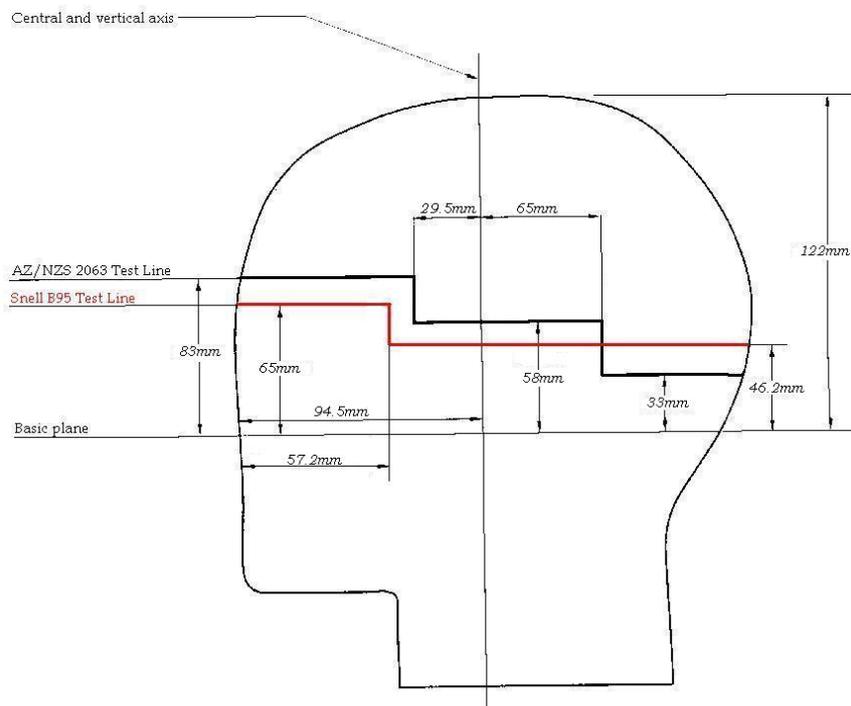


Figure 7.2. Test Line Headform E

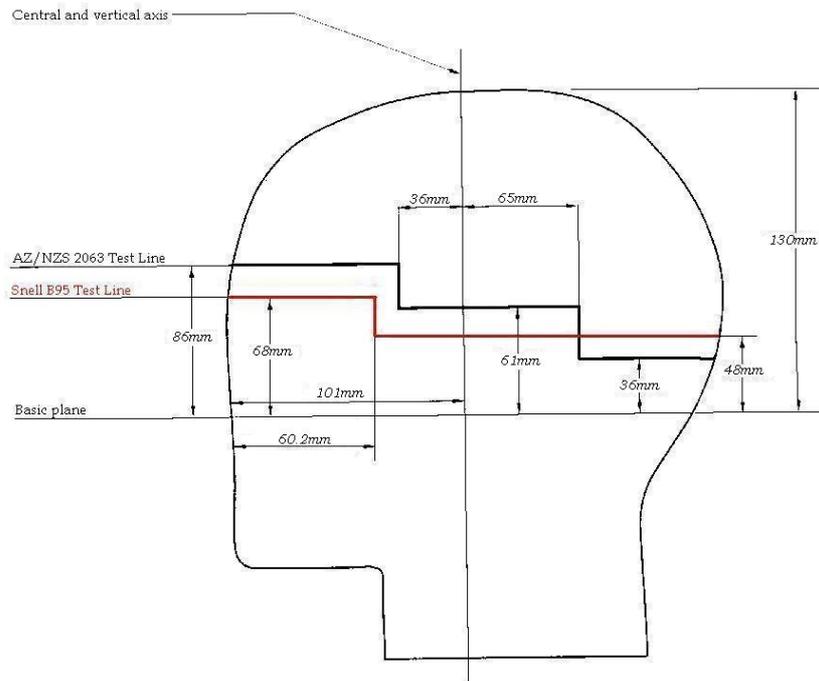


Figure 7.3. Test Line Headform J

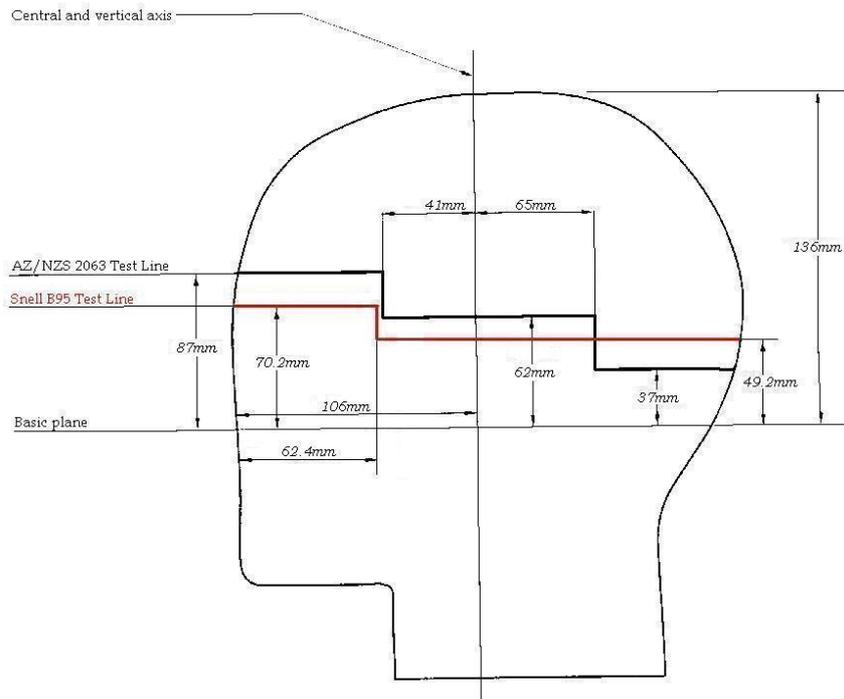


Figure 7.4. Test Line Headform M

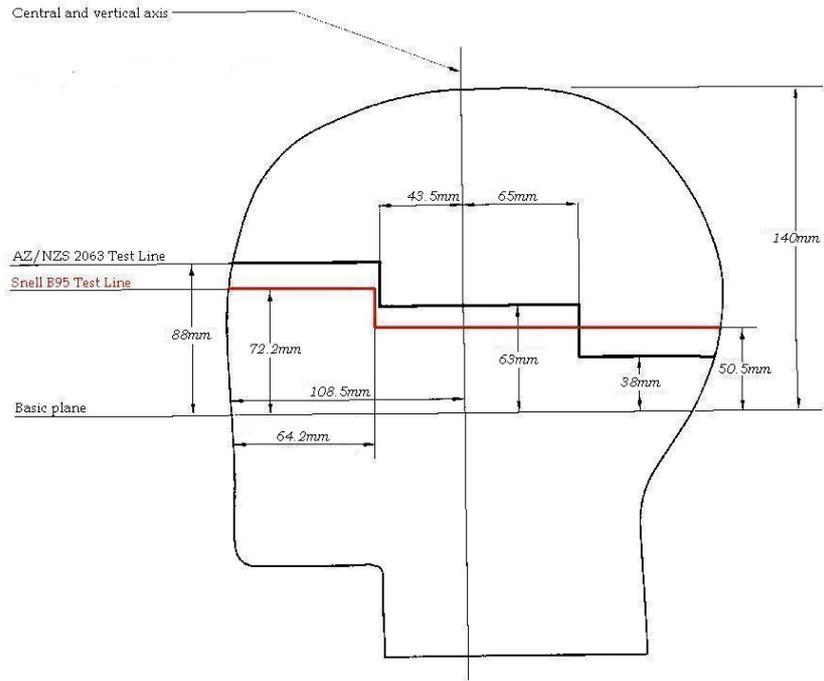


Figure 7.5. Test Line Headform O

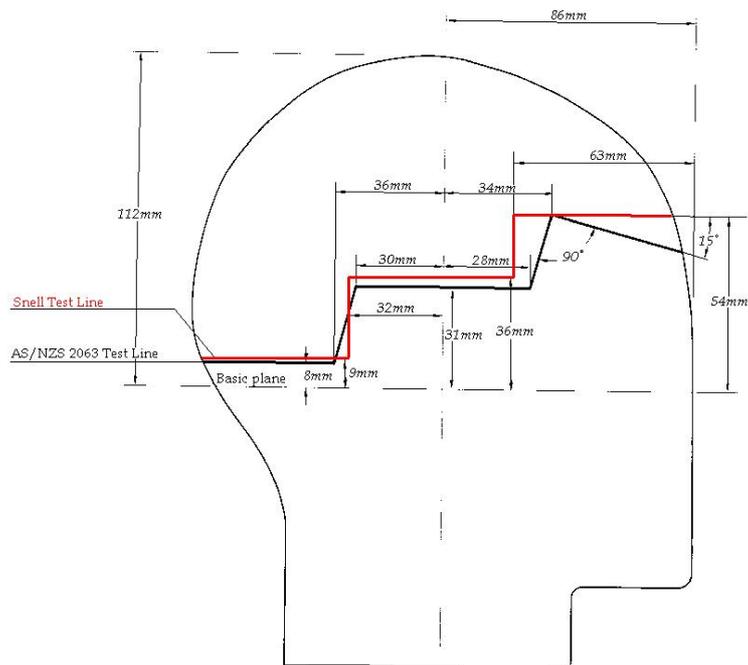


Figure 7.6. Test Line Headform AA (For Under 4 Year Old)

APPENDIX 2 – HELMET LIST

MODEL	MODEL NO.	SIZE	NO.	STANDARD	AUSTRALIAN HEADFORM	ISO HEADFORM	PRICE
NETTI QUANTUM		S 53-56	1	AS/NZS 2063	B	J	AUS\$40.50
NETTI QUANTUM	116582	M 56-59	7	AS/NZS 2063	C	J	AUS\$40.50
NETTI QUANTUM		L 59-62	1	AS/NZS 2063	C	M	AUS\$40.50
HEADSTAR T RAGE 510		S 50-54	1	AS/NZS 2063	B	E	AUS\$14.24
HEADSTAR T RAGE 510	116578	S-M	1	AS/NZS 2063	C	J	AUS\$12.34
HEADSTAR T RAGE 510		M-L	7	AS/NZS 2063	D	O	AUS\$12.34
BELL AUST STRYKER	116580	S-M 54-56	1	AS/NZS 2063	B	J	AUS\$72.00
BELL AUST STRYKER		M-L 57-59	7	AS/NZS 2063	C	J	AUS\$72.00
STAR SB 107	116579	S-M	1	AS/NZS 2063	B	J	AUS\$27.00
STAR SB 107		L-XL	7	AS/NZS 2063	C	M	AUS\$27.00
ROSEBANK MS 16		XS 48-52	1	AS/NZS 2063	B	E	AUS\$32.70
ROSEBANK MS 16		S 53-56	1	AS/NZS 2063	C	J	AUS\$32.70
ROSEBANK MS 16	116581	M-L 57-62	7	AS/NZS 2063	D	O	AUS\$32.70
HEADSTAR T	116586	M 55-60	7	Snell B95A	C	M	AUS\$20.00
HEADSTAR T		L 60-65	1	Snell B95A	D	O	AUS\$20.00
HELMET R US 08		S 50-54	1	Snell B95A	B	J	US\$5.95
HELMET R US 08	116583	M 54-58	7	Snell B95A	C	J	US\$5.95
HELMET R US 08		L 58-62	1	Snell B95A	C	M	US\$5.95
PRO RIDER BM-B12	116585	S-M	7	Snell B95A	B	J	US\$6.95
PRO RIDER BM-B12		L-XL	1	Snell B95A	C	M	US\$6.95
PRO RIDER BM-W10		XS	1	Snell B95A	A	A	US\$4.95
PRO RIDER BM-W10	116584	S-M	7	Snell B95A	C	J	US\$4.95
PRO RIDER BM-W10		L-XL	1	Snell B95A	C	M	US\$4.95

APPENDIX 3 – HELMET TEST GLOSSARY

Term	Definition
AIS	Abbreviated Injury Scale
Basic Plane	A plane through the centre of the right and left ear openings and lower edge of the eye sockets of a reference or test headform.
Helmet Positioning Index (HPI)	The distance between the forward brim of the helmet at its intersection with the mid-sagittal plane and the basic plane of the reference or test headform. The distance is determined by positioning the helmet on the headform in such a position as a user would normally wear the helmet.
Impact Energy Attenuation Test	A complete helmet is mounted on an instrumented headform and dropped, in a guided free fall, on to an anvil. The acceleration imparted to the assembly is measured.
ISS	Injury Severity Score.
Liner	The protective component or components of a helmet.
Load Distribution Test	A test in AS/NZS 2036-1996 which measured the force on a specified small area of the interior of a helmet due to impact by a 90° kerb anvil. The test was designed to replace the penetration test.
Mid-sagittal Plane	A longitudinal plane through the apex of a reference or test headform, perpendicular to the basic plane and geometrically bisecting the headform.
Penetration Test	A penetration test striker is dropped onto the outer surface of a rigidly mounted helmet positioned on a rigidly mounted test headform in a direction essentially normal to the outer surface of the helmet.
Reference Headform	A measuring device contoured to specific dimensions with surface markings indicating headform identification, the locations of the basic, mid-sagittal and reference planes, and the centres of the external ear opening.
Reference Plane	A plane parallel to the basic plane on a reference headform or test headform.
Retention System	The complete assembly by means of which the helmet is retained in position on the head during use.
Shell	A separate component to the liner or harness, and which may provide the general outer form of a helmet. This includes hard shell, thin shell, and microshell.
Test Anvils	Metal anvils used for standard testing. They include flat anvil, hemispherical anvil, and kerbstone anvil.
Test Line	A line drawn on the outer surface of a helmet coinciding with portions of the intersection of that surface in accordance with the dimensions given in the standard.

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