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KNEE WRAPS ARE DETRIMENTAL TO THE MAXIMAL SQUAT PERFORMANCE OF POWERLIFTERS COMPETING IN LOWER WEIGHT CLASSES

Andrew Naylor[1], Ariyan Ashkanfar[1], Xiaoxiao Liu[1], and Russell English[1]

[1]School of Engineering, Liverpool John Moores University, Liverpool, UK

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Abstract:

The aim of the study was to evaluate the efficacy of knee wraps for competitive powerlifters. To achieve this, an analysis of powerlifting results dating back to 1964 has been conducted. From these results the one repetition max (1RM) squat was evaluated, specifically examining the influence of competitors using knee wraps versus raw (allowing only neoprene knee sleeves). Student's t-test was used to compare the 1RM squat for male raw competitors (n=270,268) to those using wraps (n=26,576); and likewise for female raw (n=136,530) versus wraps (n=11,468). Overall, the males using wraps yielded significantly higher ($p<.05$) 1RM squat values (203 kg ± 46.8) than their raw counterparts (195 kg ± 45.7). The females yielded modest, but significantly higher ($p<.05$) 1RM squat values for raw (112 kg ± 29.3), compared to wraps (111 kg ± 29.8). The results were stratified by weight classes, and it was found that males in heavier classes (105, 120, and 120+ kg) significantly benefited ($p<.05$) from using knee wraps (+1.3, +4.8, and +6.9 kg respectively). For the lighter weight classes (59, 66, and 74 kg) knee wraps appeared significantly detrimental ($p<.05$) to the 1RM squat (-8.4, -4.4, and -3.6 kg), respectively. Only the heaviest female weight class (84 kg+) saw a significant benefit ($p<.05$) in the use of wraps with a net gain in 1RM squat of 4.5 kg. Again, wraps were shown to be significantly detrimental ($p<.05$) to the lighter weight classes (47, 52, 57, and 63 kg) with a net loss in 1RM squat (-3, -5.3, -3.6, and -3.3 kg), respectively. Considering these findings, it is suggested that only males in the heaviest three weight classes (105, 120, and 120+ kg), as well as females in the heaviest weight class (84+ kg), stand to gain any benefit from the use of knee wraps in competition.

Key words: *strength training, powerlifting, supportive gear*

Introduction

The sport of powerlifting consists of three lifts (squat, bench press, and deadlift) with three attempts allowed for each lift. During powerlifting competitions, the best successful attempts from each of the three lifts are combined to provide a total (kg). There are many federations that govern the sport of powerlifting. Although all agree on the definition and judging of what constitutes a successful squat, bench press and deadlift, not all agree on standards for supportive equipment. Furthermore, competitors are divided into weight classes with two commonly used scales. The first scale, adopted by the International Powerlifting League (IPL, 2023) is in keeping with the weight classes used throughout the 1960s and 70s. These consist of twelve classes for men (ranging from 52 kg through to 140 kg+) and twelve classes for women (ranging from 44 kg through to 110 kg+). The second scale, adopted by the International Powerlifting Federation (IPF, 2023) was devised to mirror the weight classes used in the sport of Olympic weightlifting. These consist of only eight classes for men (ranging from 59 kg to 120 kg+) and eight classes for women (ranging from 47 kg to 84 kg+).

Raw (unequipped) powerlifting does, in fact, permit competitors to use some supportive equipment. Raw competitors can either compete without any knee support, or with the use of neoprene knee sleeves with a maximum permissible length of 30 cm and thickness of 7 mm (IPF, 2023). However, the influence that knee sleeves have on squat biomechanics is minimal. Bennett, Trypuc, Valenzuela, and Sievert (2021) examined the squat of fifteen trained male and female individuals, reporting no increase in the subjects' one repetition max (1RM). Machek, Cardaci et al. (2021) reported a small but statistically significant benefit of knee sleeves through evaluation of the 1RM squat of an additional fifteen male lifters. Here, additional subjective benefits were reported such as improved proprioception, comfort, and heat retention. Herrington,

Simmonds, and Hatcher (2005) evaluated video footage of twelve females and eight males, finding that knee sleeves improved the repeatability of multi-set squats as well as moderately improving patella tracking.

Equipped powerlifting permits the use of additional supportive gear, beyond what is allowed for raw powerlifting. Single and multi-ply squat suits, as well as elasticated squat briefs, are specialist items of clothing that add a substantial amount of support to the squat (Todd, Morais, Pollack, & Todd, 2015). Furthermore, elasticated knee wraps consisting of either polyester or canvas with interwoven rubber fibres can be worn. The knee wraps can be no greater than 8 cm wide and 2 m long and can be wrapped tightly around the knee to increase the competitor's load capacity during the squat (IPF, 2023). The IPL, along with many other powerlifting federations, allow for knee wraps to be used alongside the minimal amount of lifting gear permitted in raw powerlifting. This hybrid category is known either as "classic raw" or "raw with wraps" (IPL, 2023).

One of the more comprehensive studies comparing the use of raw versus equipped powerlifters, conducted by Wilk, Krzysztofik, and Bialas (2020), evaluates 63 men and 57 women competing at the highest level of the sport. This reports a substantial difference in the 1RM squat with the equipped male competitors achieving an average of 313 kg (±56) compared to the raw competitors' average of 247 kg (±44). The female equipped competitors achieved an average 1RM squat of 225 kg (±42) compared to the raw competitors average of 170 kg (±42). Unfortunately, there is no discrimination in this study between equipped categories that allow for standard singlets, single-ply and multi-ply squat suits, so there is no guarantee that the heavier weights lifted are because of knee wraps alone. Other studies evaluating the influence of knee wraps on the squat biomechanics (Eitner, LeFavi, & Riemann, 2011; Gomes, et al., 2014; Harman & Frykman, 1990; Lake, Carden, & Shorter, 2012; Sinclair, et al., 2020) do not focus on one rep max performance, and hence the findings are inconclusive. Some interesting information is declared, such as the drawbacks of using wraps in training. It is proposed by Gomes et al. (2014) that the use of wraps for multi repetition squat sets can limit the power output and development of the musculature forming the posterior chain and quadriceps.

From the available literature (Bennett, et al., 2021; Eitner, et al., 2011; Gomes, et al., 2014; Harman & Frykman, 1990; Herrington, et al., 2005; Lake, et al., 2012; Machek, Cardaci, et al., 2021; Sinclair, et al., 2020) conclusions are drawn through experimental procedures conducted on a small number of participants. With the exception of Eitner et al. (2011), the participants in these studies carry out resistance training for purely recreational purposes and do not lift competitively. Wilk et al. (2020) conducted a more thorough study, with a higher number of participants all competing at a high level; however, this study only examined raw vs equipped lifting, making it impossible to identify the influence of knee wraps alone on the 1RM squat. As an alternative approach, the authors of the present study have turned their attention to the large body of data available from several decades of powerlifting competitions (OpenPowerlifting, 2023). These data have been used for other studies in the field of sports and exercise science (Ferland, Allard, & Comtois, 2020; Machek, et al., 2020; Machek, Lorenz, Kern, Galpin, & Bagley, 2021) but has not been used to evaluate the effectiveness of supportive gear. As such, the present study is the first to use the data to measure the net benefit (weight added to the 1RM squat) of knee wraps for male and female lifters across a standard set of weight classes. As the sport is codified into a variety of raw, classic and equipped categories, it was possible to obtain and compare 1RM squat values for competitors that have competed raw or with wraps, with no other supportive equipment used.

Methods

Study type

The study is a retrospective analysis of competitive 1RM squat values acquired from archived powerlifting results. The null hypothesis of the study was that there would be no significant difference ($p>.05$) between the observed populations competing either raw or with wraps. In conducting this study, names of competitors and locations of competitions were not stored in any repository, nor are they stated anywhere in this manuscript.

The OpenPowerlifting Data Platform

OpenPowerlifting (2023) is an open-source data platform containing the results from all major powerlifting meets held since 1964. The database allows users to filter 1RM squat results by gender, weight class and age. An important feature of OpenPowerlifting is the ability to limit search terms to show results only from certain subcategories. These categories include: "raw" permitting the use of neoprene knee sleeves; "wraps" permitting the use of knee wraps, without the aid of single or multi-ply lifting suits. The additional categories of "single-ply", "multi-ply" and "unlimited" permit the use of lifting suits as well as other supportive equipment such as elasticated squat briefs. OpenPowerlifting also allows users to rank competitors by Wilks' coefficient, which is used to adjust for bodyweight

thus allowing many federations to provide a best overall lifter award regardless of a weight class. The Wilks' formula is known to favourably bias the female 1RM squat in mid-range weight classes, with no apparent bias to the male 1RM squat (Vanderburgh & Batterham, 1999).

Statistical analysis

The complete dataset (N=2,946,532) was extracted on 17th July 2023 using Minitab v20.4 and was filtered to remove results from the federations that did not test their competitors for performance enhancing substances, and from the single-ply, multi-ply and unlimited categories. Results from children's age groups were removed (<18 years) but results from the junior category (18-24 years) were retained. This left only results for the heaviest 1RM squats from the raw (n=406,798) and wraps (n=38,044) categories. Wilks' coefficient was not used to stratify the data; instead the two datasets were divided into male and female categories for the IPF standardised weight classes (male 59, 66, 74, 83, 93, 105, 120, and 120+ kg; and female 47, 52, 57, 63, 69, 76, 84, and 84+ kg). Each dataset was tested for normality using an Anderson-Darling test, and subsequently Student's t-test was used to compare the raw and wraps results for each individual weight class. The Cohen's D score was also calculated for each weight class to determine the effects sizes using the following scale: modest effect size $d<0.2$; notable $0.2< d<0.5$; large $0.5<d<0.8$; and extra-large $d>0.8$.

Results

For almost all weight classes, the 1RM squat values significantly deviated ($p<.05$) from a normal distribution (Tables 1 and 2). This is due to the presence of outliers within the top and bottom percentiles. The only group that did not significantly deviate ($p>.05$) from a normal distribution was the 59 kg male weight class (with wraps).

When combining all weight classes for the male competitors (Table 3), the wraps category yielded significantly higher ($p<.05$) 1RM squat compared to the raw category: 203 kg (± 46.8) compared to 195 kg (± 45.7). For the individual weight classes, significantly higher ($p<.05$) 1RM squat values were observed for the wraps category in the 105, 120 and 120+ kg weight classes. Conversely, competitors in the raw category yielded significantly ($p<.05$)

Table 1. Anderson-Darling normality scores for the male 1RM squat

	Wraps				***Raw***			
Weight class (kg)	Mean ± SD (kg)	n	AD	p	Mean ± SD (kg)	n	AD	p
59	128 ± 31.9	318	0.53	.17	136 ± 34.5	6243	4.28	<.01
66	151 ± 33.9	753	1.36	<.01	155 ± 32.9	14986	13.4	<.01
74	167 ± 31.2	2538	3	<.01	170 ± 34.2	36247	38.9	<.01
83	185 ± 35.7	5653	4.71	<.01	185 ± 35.8	60175	50.7	<.01
93	199 ± 37.4	5188	5.72	<.01	198 ± 38	59151	53	<.01
105	212 ± 37.7	5321	5.18	<.01	211 ± 40.9	47352	49.2	<.01
120	228 ± 43.4	3938	5	<.01	224 ± 44.6	27968	27	<.01
120+	248 ± 49.6	2867	3.51	<.01	241 ± 53.8	18146	19.5	<.01
Pooled	203 ± 46.8	26576	20.24	<.01	195 ± 45.7	270268	230	<.01

Table 2. Anderson-Darling normality scores for the female 1RM squat

	Wraps				***Raw***			
Weight class (kg)	Mean ± SD (kg)	n	AD	p	Mean ± SD (kg)	n	AD	p
47	82.1 ± 18.7	223	0.89	.022	85.1 ± 21.5	4193	2.81	<.01
52	89.2 ± 19.2	1109	4.76	<.01	94.5 ± 21.8	10682	10.26	<.01
57	97 ± 22.5	1527	3.84	<.01	101 ± 22.8	18231	17.1	<.01
63	103 ± 22.6	1907	2.17	<.01	107 ± 24.1	26176	16.52	<.01
69	110 ± 24.6	2096	5.12	<.01	111 ± 25.7	20213	13.96	<.01
76	118 ± 27.5	1692	1.65	<.01	118 ± 26.8	22601	11.6	<.01
84	124 ± 28.1	1190	1.21	<.01	123 ± 29.3	15452	10.66	<.01
84+	135 ± 34	1724	1.2	<.01	131 ± 35.4	18982	18.44	<.01
Pooled	111 ± 29.8	11468	271	<.01	112 ± 29.3	136530	47.5	<.01

Table 3. Student's t-test results and Cohen's D effects sizes for Wraps vs. Raw

Male 1RM squat Wraps vs. raw				***Female 1RM squat Wraps vs. raw***			
t	DF	p	Cohen's D	t	DF	p	Cohen's D
4.58	355	<.01	0.254	2.35	254	.020	0.151
3.64	824	<.01	0.131	8.61	1420	<.01	0.257
5.53	2963	<.01	0.109	6.03	1797	<.01	0.160
-0.80	6763	.421	0.011	6.14	2233	<.01	0.142
-1.49	6165	.136	0.021	1.19	2593	.234	0.027
-2.27	6804	.023	0.032	-0.53	1939	.597	0.013
-6.44	5177	<.01	0.109	-1.55	1395	.123	0.046
-6.84	4008	<.01	0.133	-5.19	2077	<.01	0.128
-25.48	31768	<.01	0.165	2.69	13401	<.01	0.026

higher 1RM squat values in the 66 and 74 kg weight classes, with significantly higher ($p<.05$) 1RM squat for the 59 kg weight class. There is no significant difference between the raw and wraps groups for both the 83 kg ($p=.421$) and 93 kg ($p=.136$) weight classes.

When combining all weight classes for the female competitors (Table 3), the raw category yielded significantly higher 1RM squat values ($p<.05$) compared to the wraps category: 112 kg (± 29.3) compared to 111 kg (± 29.8). The only instance where the use of wraps yielded a significantly higher 1RM squat ($p<.05$) was for the heaviest weight class (84 kg+). Lighter weight classes using wraps (47, 52, 57, and 63 kg) yielded significantly lower ($p<.05$) 1RM squat values compared to the raw. No significant difference ($p>.05$) was observed for the 69, 76, and 84 kg weight classes.

With regards to effect sizes (Table 3), the male competitors in the 105, 120, and 120+ kg weight classes were shown benefit modestly ($d<0.2$) from using knee wraps, with the net benefit being proportional to weight class (+1.3, +4.8 and +6.9 kg, respectively). Competitors in the heaviest female weight class (84 kg+) also benefited modestly ($d<0.2$) from the use of knee wraps (4.5 kg net benefit). Both the male and female competitors reach a point where the observed phenomenon is reversed, and knee wraps have a negative impact on the 1RM squat. This is demonstrated most clearly for the male competitors in the 59 kg weight class, who see a notable loss ($d=0.254$) of -8.4 kg in the 1RM squat when using knee wraps, as well as for the 66 and 74 kg weight classes who both see a modest loss ($d<0.2$) of -4.4 and -3.6 kg, respectively. Likewise, female competitors in the lighter weight classes (47, 52, 57, and 63 kg) see a modest loss ($d<0.2$) in the 1RM squat (-3, -5.3, -3.6, and -3.3 kg, respectively).

Discussion and conclusion

The present study analysed 1RM squat data obtained directly from OpenPowerlifting. The null hypothesis of the study was that no significant difference ($p>.05$) should occur between comparable populations competing either raw or using knee wraps. This is found to be true in a few cases, such as the male 83 and 93 kg weight classes, as well as for the female 69, 76, and 84 kg weight classes. The null hypothesis was rejected in all other cases, revealing that competitors in lighter weight classes squat more competing raw compared to cohorts in the same weight classes using wraps. Only the heaviest three male weight classes (105, 120, and 120+ kg) as well as the heaviest female weight class (84+ kg) squat more using wraps compared to their raw counterparts.

When considering the normality of the data analysed, outliers in the bottom and top percentiles significantly ($p<.05$) deviate the spread of data from normal distributions for all but one of the populations evaluated. However, it should be noted that between the 1st and 99th percentiles the data are distributed normally. The reasons behind this are worthy of discussion. Using the pooled data from all the raw male lifters to exemplify this phenomenon (Figure 1), the top percentile of competitive powerlifters achieved a 1RM squat of between 300 and 490 kg, far exceeding two standard deviations from the mean and going well beyond the top tail of the distribution. These are the top 1% of an already competitive group of athletes, and hence are disproportionally stronger individuals. The sharp drop observed within the bottom percentile has a different explanation and is primarily related to the equipment available. In powerlifting competitions, the weight of the unloaded barbell presents an artificially high minimum weight that can be lifted. In

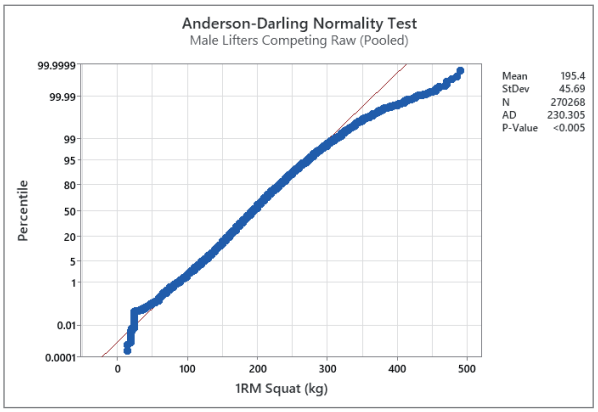

Figure 1. Anderson-Darling normality test for all male lifters competing raw.

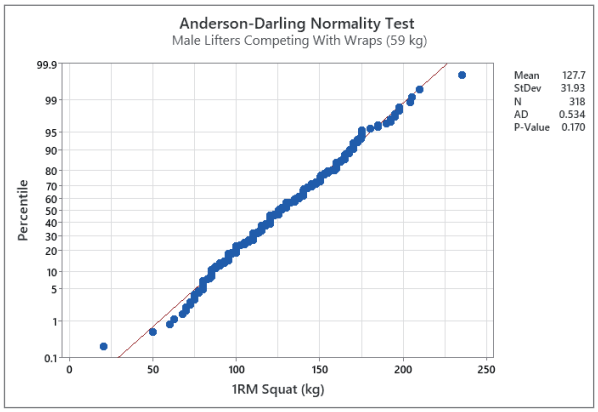

Figure 2. Anderson-Darling normality test for the male 59 kg class (wraps).

most cases this is 20 kg, the weight of a standard men's Olympic barbell. However, 15 kg (women's) and 5 kg (technique training) barbells can also be used if the competitor is not capable of squatting 20 kg. The population where the data do not significantly deviate from a normal distribution also has the one of the lowest sample sizes (n=318). This is the male 59 kg weight class using wraps (Figure 2).

The results from the present study show a modest benefit of knee wraps to heavier competitors, yet at the same show a relative disadvantage to lighter competitors. To understand why knee wraps can be advantageous for heavier competitors, while at the same time detrimental to lighter competitors, one must consider the anthropometric factors at play. Weight classes are often considered a proxy for height classes, as at the top competitive levels the heaviest competitors are most often the tallest (Keogh, Hume, Pearson, & Mellow, 2007). Taller competitors have a far greater distance between breaking parallel in the squat and completing the lift in an upright position. This requires a greater amount of mechanical work, expressed as exertion of the external force (i.e., the load applied from the barbell to the competitor) across an extended distance. Taller competitors can adjust their squat style to compensate for this disadvantage by reducing the distance required to break parallel in the squat. This may involve allowing the knee to track further forward beyond the toes, resulting in less vertical shins (Boyce & Schoenfeld, 2022). Alternatively, a wider stance can be adopted, allowing for more vertical shins and a more vertical back angle (Comfort & Kasim, 2007). Both scenarios place greater stress on the knees, making the additional support provided by the knee wraps such an appealing solution. A shorter competitor is not forced into this same mechanically disadvantageous position potentially making knee wraps unnecessary, or even counterproductive, as the data presented in the present study indicates.

Increased height is just one physical attribute competitors in heavier weight classes possess. Increased soft tissue mass (muscle and fat) is the other. Knee wraps are designed to be wrapped around the knee as tightly as possible, to maximise the elastic potential energy during the concentric phase of the squat (Inzer, 2018). Furthermore, knee wraps are only allowed to be worn 15 cm above and below the centre of the knee (IPF, 2023), where all tendons make their attachments to the patella, femur, fibula, and tibia. Competitors with a generous mass of soft tissue around the knee can comfortably wear knee wraps far tighter, allowing for greater compression around the tendons, increasing the stability of the joint without causing impingement.

A study carried out by Ferland, Pollock, et al. (2020) can help shed more light on the anthropometric factors influencing the 1RM squat for lifts executed with and without wraps. Here the 1RM squat values of 18 powerlifters and 17 American football players (all male) were scrutinised. Results from the powerlifter cohort were taken from a classic powerlifting meet, permitting the use of knee wraps. One way regression analysis was carried out to quantify the relationship between the 1RM squat and: height (H) (R^2=0.39); body mass index (BMI) (R^2=0.64) and body fat percentage (BF%) (R^2=0.32). The 1RM squat of the American footballer cohort exhibited a stronger relationship with both BMI (R^2=0.87) and BF% (R^2=0.84) when compared to the powerlifter cohort. It should be noted that American football players do not have to compete within defined weight classes, with certain positions known for having a high BMI and BF%. Offensive linemen competing in the highest level of college football weigh on average 122.4 kg (±4.7); have a BMI of 33.6 (±1); and a BF% of 25.4 (±2) (Noel, Vanheest, Zaneteas, & Rodgers, 2003). Offensive linemen are also among the tallest players on the gridiron (H = 190.6 cm ±1.2), yet the results reported from the Ferland, Pollock, et al. (2020) study shows a weaker relationship between 1RM squat and height for the American football players when compared to powerlifters (R^2 = 0.18). It is important to state that the 1RM squat

results from the American footballer cohort were obtained during the end of an offseason training cycle, without the aid of knee wraps.

The data analysed for the present study was extracted from OpenPowerlifting, hence there are limitations that must be stated. Any given powerlifter may gain or lose weight over their competitive career, and they may also choose to compete both raw and with wraps on separate occasions. Hence there will be many cases of more than one 1RM squat value originating from the same lifter. The adjudication of squat depth (i.e., thighs reaching below parallel at the bottom) carries the potential for human error from the judges during competition. The 1RM squat data will undoubtedly contain instances where judges have been lenient regarding depth, but by the same token there will be instances where depth has been achieved and the squat is logged as a failed lift by overly strict judges. This human error is moderated first by the large sample sizes, and second by excluding categories known for over lenient judging of depth (equipped using single and multi-ply squat suits). The availability of anthropometric data from OpenPowerlifting is also a limitation. Other than the weight of the competitors, there are no anthropometric characteristics on record, and hence the results can only be compared with reports from other studies regarding the potential anthropometric factors at play. A well-designed experimental study observing lifters that have extensive training experience lifting raw and with the use of wraps will shed the most light on the role of anthropometric factors. It must also be stated that the trends observed relating to competitor weight class cannot prove a causal link between bodyweight and efficacy of knee wraps. It is possible that one or more confounding variables unrelated to competitor weight play some role in the observed results. These could potentially include wrapping patterns, or even the varying quality of materials as the knee wrap has developed over the many decades it has been used in competition.

In conclusion, competitors who use knee wraps yield significantly higher 1RM squat values ($p<.05$) than their raw counterparts if they compete in heavier weight classes (105, 120, and 120+ kg for male competitors and 84+ for female competitors). Knee wraps are shown to be significantly ($p<.05$) detrimental to the 1RM squat of competitors in lighter weight classes (59, 66, and 74 kg for male competitors; and 47, 52, 57, and 63 kg for female competitors). To the knowledge of the authors of the present study, this is the first time that an analysis of such a large amount of data (raw n=406,798; wraps n=38,044) has been carried out to evaluate the efficacy of knee wraps on the 1RM squat for competitive powerlifters. When considering the practical implications of this study, powerlifters striving to achieve either a competitive 1RM squat, or a personal best in their total, should take stock of the weight class that they fall into prior to entering powerlifting competitions. The results from the present study indicate that lighter male competitors, and most female competitors, are most likely to be at their best when competing raw, and the use of knee wraps is indeed likely to adversely affect the 1RM squat. It is advisable that only powerlifters in the heavier weight classes should consider entering competitions that allow knee wraps, as they are the only competitors likely to gain an advantage from doing so.

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Correspondence to:
Andrew Naylor, Ph.D.
School of Engineering, Liverpool John Moores University
Byrom Street, Liverpool, L3 3AF, UK
Phone: +44 (0) 151 904 1531
E-mail: a.naylor1@ljmu.ac.uk

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