The influence of experience on manual materials handling and its implications for training: a systematic literature review

Mark Boococka, Liz Ashbya, Ariane Williamsa, Fiona Trevelyanb and Grant Mawstona

aHealth and Rehabilitation Research Institute and the Centre for Occupational Health and Safety Research, Auckland University of Technology, Private Bag 92006, Auckland 1142, NEW ZEALAND

Manual handling is recognised as a major cause of work-related back injuries. Although widely implemented, manual handling training programmes appear to have had limited success in reducing these injuries. This may stem from the inadequacy of training programmes and/or their inability to accommodate variations in task, workplace, and worker. Designing training programmes based on the techniques of experienced workers may provide an effective approach for injury prevention, although the differences in strategies adopted by experienced and novice workers are not well documented. A systematic review of the literature was undertaken to investigate variations in handling techniques and musculoskeletal risk factors observed between experienced and novices when performing manual handling tasks. Twenty three articles met the inclusion criteria of this review. Studies incorporated a range of outcome measures, including kinematic and kinetic variables (e.g. back moments, spinal compression forces, trunk velocities, static strength, postural deviations, hand positions, trunk stability), muscle activity (EMG), muscle oxygenation and maximum acceptable weight of lift. The majority of studies (n=16) evaluated differences in box handling techniques between experts and novices. Other tasks compared included: pushing and pulling; isometric lifting strength, patient transfers; sheeprerming and wool handling. Conflicting findings were found when comparing spinal compression and sheer forces, and lumbar moments of novices and experts. In the majority of studies, footwork, load manoeuvring, handgrip and body posture often differentiated experts from novices. One study reported increased levels of low back muscle oxygenation in novices when compared to expert handlers, suggesting more efficient motor strategies adopted by the experienced workers.

Practitioner Summary: Involving knowledgeable employees, ensuring an appropriate ergonomic assessment of the task(s), and tailoring training to task requirements appear to be important ingredients for delivering an effective manual handling training programme. The handling techniques adopted by experts and novices appear to differ significantly and implementing ‘expert techniques’ into manual training programmes may provide for a more effective approach for reducing the risk of injury in manual handling jobs.

Keywords: Manual handling, training, experts versus novices, musculoskeletal injuries, systematic review

1. Introduction

Back injuries are a major cause of work-related ill-health and absenteeism, costing New Zealand an estimated NZ$230M in 2010-2011 (Accident Compensation Corporation, 2012). Risks associated with manual handling have been identified as a major cause of these injuries (Dempsey, 1998). Although widely implemented, manual handling training programmes appear to have had limited success in reducing low back injuries and their effectiveness has been contested. This may stem from the inadequacy of training programmes and their inability to accommodate variations in task, workplace, and worker (Gagnon, 2003). Designing training programmes based on the techniques of experienced workers may provide an effective approach for injury prevention, although the differences in strategies adopted by experienced and novice workers are not well documented. A systematic review of the literature was undertaken to investigate variations in handling techniques and musculoskeletal risk factors observed between experienced and novices when performing manual handling tasks.
2. Methods

2.1 Literature search

A search of six electronic databases (Scopus, Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Sport Discuss, Healthsource: Nursing/Academic Edition, and Psychology and Behavioural Sciences Collection) was conducted to identify studies comparing participants of differing experience when performing manual handling tasks. The search strategy combined keywords inclusive of: manual handling; skill level (experience and/or novice); and outcome measures (e.g. kinematic, movement strategy). Following the exclusion of duplicates, articles were screened by title and abstract for relevance. Full text articles of those studies considered appropriate to the review were screened against inclusion/exclusion criteria. The search was completed in January 2015.

2.2 Inclusion/exclusion criteria

The review was restricted to experimental studies investigating the differences in manual handling task performed by ‘novice’ and ‘expert’ handlers. Studies were required to: 1) be experimental in design; 2) investigate differences in task performance of participants with different levels of experience (e.g. experienced versus novice); 3) involve biomechanical, physiological or psychophysical outcome measures; 4) be published in English; and 5) be available online in full-text format. No restrictions were imposed on the date of publication.

2.3 Methodological assessment

The methodological quality of each study was critiqued and scored by two independent reviewers using a modified version of the Quality Index (QI) tool originally described by Downs and Black (1998). The QI tool consists of 27 items that assess a study’s internal and external validity, data reporting and study power. The tool was modified to exclude nine questions that were not considered relevant to this review, resulting in the retention of 18 questions. Of the remaining questions and with the exception of question five (0 = no, 1 = partially, 2 = yes), the scoring system graded each question as either 0 (no/unable to determine) or 1 (yes). The summed score for each study was calculated and the maximum achievable score was 19.

3. Results

3.1 Study selection

Following the initial search, 685 studies were identified, 58 of which were considered appropriate for full text review (Figure 1). Thirty-seven articles were excluded following full text review and an additional two studies were identified following a review of article reference lists, leaving 23 articles in total. Articles were excluded due to: a failure to compare subjects of differing experience levels (n=26); outcomes not involving biomechanical, physiological, or psychophysical measures (n=5), the study design being non-experimental (n=3), no full text being available (n=2); and not being available in the English language (n=1). One study did not investigate a manual material handling task. Data was extracted from each study and included information on study objectives, participant information, task/activity assessed, outcome measures, and study findings (Table 1).

3.2 Overview of studies and their methodological quality

The majority of studies investigated differences in lifting and lowering strategies of novice and experts when lifting/lowering or transferring boxes (n=16). Two studies investigated differences associated with patient transfers and two with the activity of sheep shearing. Other tasks evaluated included: isometric lifting; pushing and pulling; and wool handling. The methodological quality of studies varied with QI scores ranging from 5 to 13 out of a possible 19 (median QI=10).

Studies incorporated a range of outcome measures, including: kinematic and kinetic variables (e.g. back moments, spinal compression forces, static strength, trunk velocities, postural deviations, hand positions, trunk stability); muscle activity (EMG); muscle oxygenation; back discomfort; and maximum acceptable weight of lift (MAWL). Considerable variations existed in the definition of experts and novices, with experts ranging from 1 to 20 years’ experience. Some studies identified experts as having low incidence rate of handling injuries and were considered competent by colleagues and managers. Novices were often taken
from student populations with no or some (3-6 months) handling experience. Findings from each of the studies are grouped according to: handling strategies; postural kinematics; biomechanical loading and force exertions; and psychophysical and physiological measures.

**Figure 1. Results of the literature search**

### 3.3 Handling strategies

#### 3.3.1 Feet and body positioning

Five studies compared the foot and trunk positioning of experts and novices when lifting/lowering or transferring boxes (Authier et al., 1995; Authier et al., 1996; Gagnon, 2006; Lee and Nussbaum, 2012; Plamondon et al., 2014). Conflicting findings were reported between novices and experts for body position (facing or turned) and body support (balanced or on one foot) at the start and finish of the handling task. While Lee and Nussbaum (2012) found experts positioned their feet approximately 5cm further from the box than novices during lifting, Plamondon et al. (2014), Authier et al. (1996) and Authier et al. (1995) found that experts positioned themselves closer to the box or brought the box closer to themselves than novices.
Table 1. Summary of included studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Subjects</th>
<th>Task</th>
<th>No. peri (N)</th>
<th>Expos (E)</th>
<th>Outcome measures</th>
<th>QI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yang et al.</td>
<td>15 15</td>
<td>Box handling</td>
<td>3-6 months</td>
<td>&gt; 5 yr experience, low incidence &amp; no injury in preceding yr</td>
<td>Whole body kinematics and spine moments</td>
<td>12</td>
</tr>
<tr>
<td>Plamondon et al. (2010)</td>
<td>15 15</td>
<td>Box handling</td>
<td>3-6 months</td>
<td>&gt; 5 yr experience, low incidence &amp; no injury in preceding yr</td>
<td>Whole body kinematics and spine moments</td>
<td>11</td>
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<td>Plamondon et al. (2014)</td>
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<td>11</td>
</tr>
</tbody>
</table>

15 Subjects
15 No. peri (N)
12 Expos (E)
10 Outcome measures
9 QI*

MH= manual handling

Author et al. (2010) vs. Plamondon et al. (2010)

<table>
<thead>
<tr>
<th>Author</th>
<th>Subjects</th>
<th>Task</th>
<th>No. peri (N)</th>
<th>Expos (E)</th>
<th>Outcome measures</th>
<th>QI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authier et al.</td>
<td>6 6</td>
<td>Box handling</td>
<td>Min 3 months MH experience</td>
<td>20 yr experience, low incidence of handling accidents</td>
<td>Postural and box kinematics</td>
<td>10</td>
</tr>
<tr>
<td>Authier et al.</td>
<td>6 6</td>
<td>Box handling</td>
<td>Min 3 months MH experience</td>
<td>20 yr experience, low incidence of handling accidents</td>
<td>Postural and box kinematics</td>
<td>10</td>
</tr>
<tr>
<td>Chany et al.</td>
<td>12 12</td>
<td>Box handling</td>
<td>No MH experience</td>
<td>At least 1yr MH experience</td>
<td>Static lifting strength and whole body kinematics</td>
<td>10</td>
</tr>
<tr>
<td>Chen et al.</td>
<td>21 21</td>
<td>Box handling</td>
<td>No MH experience</td>
<td>At least 2yr experience in manual lifting from hypermarket</td>
<td>Whole body kinematics</td>
<td>5</td>
</tr>
<tr>
<td>Gagnon</td>
<td>5 6</td>
<td>Box handling</td>
<td>Part-time MH workers</td>
<td>At least 10yr MH experience</td>
<td>Whole body kinematics</td>
<td>5</td>
</tr>
<tr>
<td>Gagnon et al.</td>
<td>5 6</td>
<td>Box handling</td>
<td>Min 3 months MH experience</td>
<td>Considered by managers and colleagues as the most competent</td>
<td>Net spinal reaction moments, knee and trunk kinematics and feet spacing</td>
<td>11</td>
</tr>
<tr>
<td>Granata et al.</td>
<td>7 5</td>
<td>Box handling</td>
<td>College students with no experience</td>
<td>Warehouse selectors from a local distribution centre</td>
<td>Spinal compression and shear forces</td>
<td>9</td>
</tr>
<tr>
<td>Gregory et al.</td>
<td>5 7</td>
<td>Sheep shearing</td>
<td>Senior class shearers</td>
<td>Open class</td>
<td>Spinal compression and shear forces, and joint moments</td>
<td>11</td>
</tr>
<tr>
<td>Hodder</td>
<td>12 10</td>
<td>Patient transfers</td>
<td>No MH experience</td>
<td>Trained in back injury prevention program within 2yr</td>
<td>EMG, thoracolumbar displacement</td>
<td>10</td>
</tr>
<tr>
<td>Kier &amp; MacDonell (2004)</td>
<td>4 3</td>
<td>Patient transfers</td>
<td>Little or no experience</td>
<td>Involved with training and instruction</td>
<td>EMG</td>
<td>10</td>
</tr>
<tr>
<td>Lee et al.</td>
<td>6 6</td>
<td>Box handling</td>
<td>No experience in frequent lifting</td>
<td>At least 2.5yr recent experience in frequent lifting tasks</td>
<td>Torso kinematics &amp; kinetics</td>
<td>12</td>
</tr>
<tr>
<td>Lee &amp; Nussbaum (2013)</td>
<td>6 6</td>
<td>Box handling</td>
<td>No experience in frequent lifting</td>
<td>&gt;3yr frequent lifting tasks for at least 10hr/wk, from local warehouse</td>
<td>Whole body balance and torso stability</td>
<td>12</td>
</tr>
<tr>
<td>Lee &amp; Nussbaum (2012)</td>
<td>6 6</td>
<td>Box handling</td>
<td>No experience in frequent lifting tasks</td>
<td>&gt;3yr frequent lifting tasks for at least 10hr/wk, from local warehouse</td>
<td>Torso kinematics, foot distance, peak &amp; cumulative lumbar moments</td>
<td>12</td>
</tr>
<tr>
<td>Lett &amp; McGill</td>
<td>5 4</td>
<td>Pushing/pulling</td>
<td>No MH experience</td>
<td>Firefighters trained in pushing/pulling tasks</td>
<td>EMG, whole body kinematics, spinal compression and shear forces</td>
<td>10</td>
</tr>
<tr>
<td>Mramas et al.</td>
<td>12 12</td>
<td>Box handling</td>
<td>No experience in frequent lifting</td>
<td>At least 1 yr MH experience</td>
<td>Spinal compression and shear forces, and joint moments</td>
<td>10</td>
</tr>
<tr>
<td>Milosavlievic et al. (2011)</td>
<td>40 20</td>
<td>Wool handling</td>
<td>Junior or senior grade</td>
<td>Open class grade sheep shearers</td>
<td>Lumbar kinematics</td>
<td>13</td>
</tr>
<tr>
<td>Mital (1987)</td>
<td>74 74</td>
<td>Box handling</td>
<td>Students</td>
<td>Industrial workers</td>
<td>MAWL, heart rates and oxygen uptake</td>
<td>10</td>
</tr>
<tr>
<td>Pal et al.</td>
<td>39 41</td>
<td>Sheep shearing</td>
<td>Senior, intermediate</td>
<td>Senior and open class</td>
<td>Trunk kinematics, spinal compression and shear forces, joint moments</td>
<td>12</td>
</tr>
<tr>
<td>Parakkat</td>
<td>12 12</td>
<td>Box handling</td>
<td>Students</td>
<td>At least 1 yr experience from local grocery stores and distribution centres</td>
<td>Back discomfort rating</td>
<td>10</td>
</tr>
<tr>
<td>Plamondon et al. (2007)</td>
<td>15 15</td>
<td>Box handling</td>
<td>3-6 months experience and no injury in preceding yr</td>
<td>&gt; 5 yr experience, low incidence &amp; no injury in preceding yr, recommendations from peers, unions or managers</td>
<td>Whole body kinematics and spine moments</td>
<td>11</td>
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<td>Plamondon et al. (2014)</td>
<td>15 15</td>
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<td>11</td>
</tr>
</tbody>
</table>

*QI=Quality Index; ^MH=manual handling
3.3.2 Hand and box positioning

Four studies examined the hand and box positioning adopted by experts and novices when lifting/lowering and transferring boxes (Authier et al., 1995; Authier et al., 1996; Gagnon, 2006; Plamondon et al., 2010). Three studies (Authier et al., 1995; Authier et al., 1996; Gagnon, 2006) found that when lifting, experts employed a strategy of tilting the box prior to the lift and often imparted an impulse to the box at take-off or early in the transfer. Conversely, novices typically grasped the box in a low position, at a distance from their body, and did not tilt the box prior to lifting. When handling boxes, Authier et al. (1996) noted that experts employed a wide range of grips, though favoured diagonal grips and those on the corners of the box, while novices in a subsequent study typically grasped the box with the handgrips underneath the box (Gagnon, 2006). Plamondon et al. (2010) identified box height to be a differentiating factor in the strategies of experts and novices and found that the closer the hands were to the ground, the greater was the difference in hand positioning between experts and novices. Gagnon et al. (2006) noted that during lowering tasks, experts reduced the trajectory over which the load remained supported, while novices increased the supported trajectory. This was suggested to lead to increased energy expenditure in novice workers when compared to experts.

3.3.3 Stepping strategies

Two studies examined stepping strategies of novices and experts during box transfer tasks (Authier et al., 1996; Gagnon, 2006). Both studies found that experts favoured shorter steps when carrying boxes, rather than one long step adopted by novices.

3.4 Postural kinematics

3.4.1 Spine and trunk postures

Twelve studies examined the differences in spine and trunk postures between novices and experts when performing manual handling tasks (Authier et al., 1995; Authier et al., 1996; Gagnon, 2006; Hodder et al., 2010; Pal et al., 2010; Plamondon et al., 2010; Milosavljevic et al., 2011; Lee and Nussbaum, 2012; Plamondon et al., 2012; Lee and Nussbaum, 2013; Lee et al., 2014; Plamondon et al., 2014). Of these, nine investigated manual handling tasks involving box transfers or lifting/lowering a box. The remaining three studies involved patient transfers, sheep shearing and wool handling.

Two studies (Plamondon et al., 2010; Plamondon et al., 2012) found that experts flexed their lumbar spine and upper trunk significantly less than novices when transferring boxes. Lumbar torsion angle and lumbar flexion angular velocity were also significantly increased in experts. Conversely, Authier et al. (1995) and Authier (1996) found no difference in the degree of spinal flexion, lateral asymmetry, and axial asymmetry between novices and experts when transferring boxes, while a second study found novices increased trunk rotation during transfers (Gagnon, 2006). Lee and Nussbaum (2012) also found no significant effects of experience on peak lumbar angle or velocity when lifting and lowering a box, though experts displayed higher peak lumbar angular acceleration.

During patient handling tasks, Hodder et al. (2010) found experienced nurses reduced thoracolumbar spine angles, decreased the range of spine motion, and displayed lower variability in spine angles when compared to novices. When comparing expert and novice shearsers and wool handlers, Pal et al. (2010) and Milosavljevic et al. (2011) generally found that more experienced workers spent less time in end range of flexion and more time in neutral lateral bend and axially twisted postures than inexperienced workers.

3.4.2 Knee posture

Eight studies examined the differences between the knee angles of novices and experts during manual handling tasks (Authier et al., 1995; Authier et al., 1996; Gagnon et al., 1996; Gagnon, 2006; Plamondon et al., 2010; Chen et al., 2011; Plamondon et al., 2012; Plamondon et al., 2014). All examined manual handling tasks involving box transfers or lifting and lowering boxes.
Three studies found experts adopted decreased knee flexion when compared with novices during box transfer tasks, with one study reporting a reduction in total knee excursion (Authier et al., 1995; Authier et al., 1996; Gagnon, 2006). Conversely, Plamondon et al. (2010) and Plamondon et al. (2012) found that during the lifting and deposit phases of a lifting/lowering task, at the time of the peak resultant moment, experts displayed greater knee flexion than novices, bringing them closer to the box. Chen et al. (2011) also found greater knee flexion in experienced workers when performing maximum isometric vertical force exertions.

3.4 Biomechanical loading and force exertions

3.4.1 Spinal loading
Six studies examined the effects of experience on spinal loading during manual handling tasks (Granata et al., 1999; Chany et al., 2006; Lett and McGill, 2006; Marras et al., 2006; Pal et al., 2010; Milosavljevic et al., 2011). Of these, three investigated lifting/lowering or box-transferring tasks. Other tasks included pushing and pulling, sheep shearing and wool handling. For a box lifting task, Granata et al. (1999) found higher spinal compression, anterior-posterior shear forces, and lateral shear forces among experts when compared to novices. Similarly, Milosavljevic et al. (2011) found more experienced wool handlers produced higher medio-lateral reaction shear forces than novices. In contrast, Lett & McGill (2006) found that novices produced higher peak posterior shear forces than experts when pushing and pulling.

Studies by Marras et al (2006) and Chany et al. (2006) point to a complex interaction of factors, of which experience may only be one factor. Marras et al (2006) found that experts increased spinal loading when working at slower handling rates of lift and increased load moments, while novices increased spinal loading at faster rates and lower load moments. Chany et al. (2006) found an interaction between personality traits, experience, load moment and lift frequency on spinal loading.

3.4.2 Lumbar moments
Seven studies examined the lumbar moments generated by novices and experts during manual handling tasks (Authier et al., 1995; Gagnon, 2006; Plamondon et al., 2010; Lee and Nussbaum, 2012; Lee and Nussbaum, 2013; Lee et al., 2014; Plamondon et al., 2014). Six studies investigated box lifting or transferring tasks, and one study the task of sheep shearing.

Lee et al. (2014) found that for repetitive lifting and lowering, novices displayed reduced peak lateral bending moments, while experts had increased peak twisting moments. For the same task, peak moments in the sagittal plane were also found to be higher in experts (Lee and Nussbaum, 2012). Conversely, during box-transferring tasks, Plamondon et al. (2014; 2012) found no significant differences in peak resultant moments between experts and novices, although experts produce lower values on average.

3.4.3 Muscle activity
Three studies reported on the muscle activity of experts and novices during patient handling and push/pull tasks (Keir and MacDonell, 2004; Lett and McGill, 2006; Hodder et al., 2010). For push/pull tasks, Lett & McGill (2006) found experts generated lower levels of trunk muscle activity than novices, which they considered representative of more efficient techniques. Whilst Hodder et al. (2010) reported lower erector spinae muscle activity in experts when compared to novices during patient transfer tasks, this relationship was not consistent across all muscle groups. For example, experts showed twice as much trapezius and latissimus dorsi activity than novices which they suggested was a strategy of experts to reduce lower back loading at the expense of increased shoulder girdle muscle activity.

3.4.4 Strength
One study investigated the effects of experience on isometric lifting strength across 15 lifting heights (Chen et al., 2011). No difference was found between experts and novices for ‘toward body lifts’ with increasing lifting height. However, when lifting vertically, lifting height had a significantly effect on force exertions in novices, but not experts. A significant difference was also found in lifting strength between experts and novices when lifting vertically at heights of between 100 and 120cm.

3.5 Psychophysical: MAWL and back discomfort
Mital et al. (1987) compared the MAWL of experts and novices. The study found male novices accepted on average 11% less weight than their expert counterparts over an eight-hour period, while females accepted 6% less. These differences decreased to 2% in both groups over a 12-hour shift. Reductions in MAWL were similar between experts and novices up to four lifts per minute, beyond which a sharp reduction in MAWL occurred for experts than for novices.

Parakkat et al. (2007) found that back discomfort was significantly influenced by lifting experience, with novices reporting much higher discomfort levels than their experienced counterparts. Load moment arm significantly influenced discomfort levels in novices, whereas experts had low levels of discomfort irrespective of moment arm, lift frequency or duration.

### 3.6 Physiological: oxygen saturation

One study (Yang et al., 2007) compared low back muscle oxygen saturation in novices and experts during a repetitive lifting task. Although oxygen saturation increased in both groups throughout the trial, the increase for expert subjects was significantly lower than for novices and was suggested to stem from more efficient motor strategies of the experienced workers.

### 4. Discussion

Evidence from the literature suggests differences in the kinematic and kinetic strategies adopted by experts and novices when performing manual handling tasks. However, conflicting evidence across studies appears to reflect the variability in study designs, task activities, definition of expert, and/or outcome measures used to determine performance or injury risk. Some findings are also suggestive of a complex interaction of risk factors that increase the likelihood of musculoskeletal injury, of which experience appears to be one factor.

There was some evidence that postures adopted by experts and novices do differ, particular during stressful stages of the lift, e.g. the initial lifting of the load when peak resultant moments are often high (Plamondon et al., 2014). Experts also appear to adopt strategies that reduce asymmetry and mechanical work that may have consequences for reducing back loading. However, findings from studies of spinal compression and shear forces, and lumbar moments are contradictory. In some studies experienced workers have been shown to increase spinal compression loading (20%) and have higher spine extension moments than novices, which was suggested to improve spine stability (increased muscle co-activity) and balance (Lee and Nußbaum, 2013). Measures of physical and psychophysical differences between experts and novices are limited. Evidence of lower levels of oxygen saturation of the erector spinae for a given workload has been found in experts (Yang et al., 2007) and suggested to stem from reduced metabolic demands within local muscle tissue and more efficient motor strategies, or improved back muscle adaptations. This may have implication for novices towards the end of the workday and the scheduling of rest breaks to decrease the risk of musculoskeletal injury. There is a need for clear definitions of novices and experts, as this varied widely across studies. For example, the definitions used to classify experts ranged between 1 to 20 years. The low number of participants in the majority of the studies were also considered (approximately 50% of the studies with fewer than 7 participants per group) has potential implications for study power.

Involving knowledgeable employees, ensuring an appropriate ergonomic assessment of the task(s), and tailoring training to task requirements appear to be important ingredients for delivering an effective manual handling training programme. Ensuring meaningful, challenging and familiar contributes to task realism also appears important (Farrington-Darby and Wilson, 2006), and the content and adherence to training programmes is rarely questioned in intervention studies. Given the evidence for differences in the handling techniques adopted by experts and novices, implementing ‘expert techniques’ into manual training programmes may provide for a more effective approach for reducing the risk of injury in manual handling jobs.

### Acknowledgements

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### References


