# Evaluation of the occupational hazard perception of building construction workers from a psychometric paradigm and considering sociodemographic variables

## Evaluación de la percepción de riesgo ocupacional de trabajadores de la construcción desde un paradigma psicométrico y considerando variables sociodemográficas

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**Abstract**
Historically, the construction industry has presented high accident rates, and in order to get a deeper understanding and making right decisions, it is interesting to consider the risks from a worker's point of view. This research addresses the perception of risks by construction workers from a psychometric paradigm and considering some sociodemographic variables. The study considered a sample consisted of a group of workers who belong to the Chilean construction industry, particularly from the building construction sector. Relevant risks associated with a high accident rate were identified through an extensive literature review. In addition, the relative risk related to physical overexertion and that related to the exposure to physical and chemical agents are considered. Based on a psychometric approach for the evaluation of qualitative attributes, a measurement instrument was applied; results were then statistically analyzed. Additionally, the incidence of sociodemographic variables was evaluated: age, profession, experience and educational level in relation to the perceived risk level. Statistically significant differences of the perceived risk associated to noise exposure, depending on the age of the workers were obtained. On the other hand, it was determined that workers with the most experience consider that those jobs that involve uncomfortable or forced postures constitute a relevant physical risk. Meanwhile, jobs such as: rebar workers, bricklayers and concrete workers, perceive the gravity and immediacy of the effect associated to risk significantly more in activities that involve repetitive movements.

**Key words**: Risk perception, building construction, psychometric paradigm, sociodemographic variables, accident rate, physical overexertion, exposure to physical and chemical agents.

**Resumen**
Históricamente, la industria de la construcción ha presentado altas tasas de accidentes, y para comprender mejor y tomar decisiones correctas, es interesante considerar los riesgos desde el punto de vista del trabajador. Esta investigación aborda la percepción de riesgos por parte de los trabajadores de la construcción, desde un paradigma psicométrico y considerando algunas variables sociodemográficas. El estudio consideró una muestra consistente en un grupo de trabajadores que pertenecen a la industria de la construcción chilena, particularmente del sector de edificación. A través de una extensa revisión bibliográfica, se identificaron los riesgos más relevantes asociados a una alta tasa de accidentes. Además, se consideró el riesgo relativo relacionado con el esfuerzo físico excesivo y aquel relacionado con la exposición a agentes físicos y químicos.

Basado en un enfoque psicométrico para la evaluación de atributos cualitativos, se aplicó un instrumento de medición; los resultados fueron luego analizados estadísticamente. Adicionalmente, se evaluó la incidencia de variables sociodemográficas: edad, profesión, experiencia y nivel educativo, en relación con el nivel de riesgo percibido. Se obtuvieron diferencias estadísticamente significativas del riesgo percibido asociado a la exposición al ruido, dependiendo de la edad de los trabajadores. Por otro lado, se determinó que los trabajadores con más experiencia consideran que los trabajos que involucran posturas incómodas o forzadas constituyen un riesgo físico relevante. Mientras tanto, trabajadores tales como: enfierradores, albañiles y concreteros, perciben de forma más significativa la gravedad y la inmediatez del efecto asociado al riesgo, en actividades que implican movimientos repetitivos.

**Palabras clave:** percepción de riesgo, edificación, paradigma psicométrico, variables sociodemográficas, tasa de accidentes, esfuerzo físico excesivo, exposición a agentes físicos y químicos.

## Introduction

It is known that the construction industry presents a high rate in working accidents (Akintoye & MacLeod, 1997; Chen et al., 2015), with important economic and social impacts (Johnson & Covello, 2012). For this reason, the incorporation of risk prevention in construction procedures is fundamental to reduce accidents, where a number of indexed articles have published about risk prevention, going as back as works conducted by Fischhoff et al. (1978) up today with researches leaded by Hallowell (2010), Rodríguez-Garzón et al. (2013, 2015, 2016), among others. The reduction of accident rates in this sector does not coincide with the advances accomplished in terms of quality and speed of the construction processes (Rubio et al., 2011). A high number of subcontracts, the concurrence of multiple companies in each project, workforce that is not always specialized, incomplete definition in projects, unforeseen events of the work, and occasionally, non-compliance with regulations are factors that in a certain way affect the reduction of accident rate in the construction sector (Peralta & Serpell, 1991; Rubio et al., 2011; Chen et al., 2015). Having so many variables affecting the incidence of accidents, it would be helpful that the people in charge of works know the risk perception by workers, as their perception could be very close to reality, because they have experienced the risks and they have to be thinking about them regularly (Stewart-Taylor & Cherrie, 1998; Rickard, 2014). In this sense, it should be noted that the behavior of workers when facing everyday risks depends on the perception that they have of them (Stewart-Taylor & Cherrie, 1998; Rickard, 2014). However, despite various authors consider risk perception as a precursor of self-protection or as indicator of a safe working behavior (Harrell, 1990; Cox & Cox, 1991; Will & Geller, 2004), the measurement of risk perception in construction from a psychometric paradigm has not been studied exhaustively (Rodríguez-Garzón et al., 2013).

Experimental studies performed by Straus et al. (2009) and Graham et al. (2006) regarding certain types of risk (in particular the use of sunblock in workers and operations engineers) demonstrate that when the individual's perception of risk increases, the intention for behavioral change increases as well, with favorable effects on health.

In congruence with the above, knowing the perceived risk will improve the strategies of intervention in construction safety, a notorious sector by its high accident rate. Thus, the evaluation of risk perception from a psychometric paradigm and taking into account some sociodemographic variables, will allow dangers, which workers consider as threats in their work, to be known more precisely.

In this way, the general objective for this research is to evaluate the perceived risk by workers from the construction industry from a psychometric paradigm. The specific objectives: (1) determine through an extensive bibliographic revision, the factors that influence risk perception, and job hazards with a higher accident rate in the construction industry; (2) analyze risk perception according to literature within workers who participated in this study; (3) from the results, determine a characteristic profile of the building construction worker and; (4) analyze the incidence of the sociodemographic variables of the workers about the perceived risks.

## Review of Literature

### Construction Industry

Construction is highly relevant to the economy because it is related to all economic sectors. This is because it provides the physical infrastructure for development and productive operation, having a direct participation in domestic product and investment. In addition, this industry is characterized by having a productive chain, which favors the coordination and collaboration among the parts of the sector, which results in agglutination factor that facilitates the realization of common initiatives (Betts & Farrell, 2009).

However, the construction industry is characterized by its economic instability; meaning that it is an area sensitive to the changes that countries' economic cycles experience. This means that it can pick up slowly in expansion periods, and conversely, it can be affected more rapidly during the periods of economic recession (Peralta & Serpell, 1991).

Historically, the construction industry has represented an important percentage of the GDP worldwide, and due to its continuous growth, it is estimated that it could reach even a 13% of the world GDP in 2020 expanding over a 5% every year (Betts & Farrell, 2009).

On the other hand, to understand the construction industry, authors such as Oglesby et al. (1989) and Duhart (1984) state that construction is generally characterized by having low-skilled workforce, with a certain degree of unreliability in its performance and marked by short-term relationships. In addition, construction is far more dangerous than the majority of the rest of the economic sectors (International Labour Organization, 2005; Shamsuddin et al., 2015).

**Risk Prevention and Risks in Construction**

Even though, over time there have been important technological advances in construction procedures, they have not always had an effect on the prevention of accidents or the reduction on accident rates. As an example, authors such as Lorent (1991), point out that to prevent working risks is profitable, considering that in the 90's in Luxembourg only a 1.5% of the total cost of construction was destined to accident prevention. López et al. (2008) bring up that companies do not calculate prevention or accident costs; they then stated the need to increase the efforts related to the safety of workers.

It could be expected that safety in construction projects improves over the years; however, that is not a reality everywhere. Just by way of example, in terms of accident rates in countries like the United States, construction mortality rate in 2015 had the highest levels since 2008, where the most affected were carpenters and electricians (Bureau of Labor Statistics, 2016). To give another example, in Chile, fatal accidents in construction increased 100% between 2015 and 2016 (CChC, 2017). And considering that the largest percentage of accidents in construction happen due to lack of control followed by unsafe acts (Chinchilla, 2002), accident prevention is a challenge which involves the senior management of organizations, construction professionals, risk prevention experts, joint committees, and workers themselves (CChC, 2017).

In this sense, one of the main points of this research was to identify the main risks to which workers are exposed every day in this sector. For this, an extensive literature review was carried out, and those working accidents with the highest accident rates were identified.

Several studies indicate that falls from different levels and the struck by objects, represent two of the main causes of death in construction (Herman, 2000; JICOSH, 2001; Jackson & Loomis, 2002; Colantonio et al., 2009; INSHT, 2010). The most affected by falls from heights are workers who are older than 55 years old due to loss of agility and reaction capacity (Kemmler & Lundholm, 2001). Caught-in/between by collapse of the structure and electrocution in workers between 19 and 25 years old (Herman, 2000; Jackson & Loomis, 2002; Janicak, 2008), complete the so-called "fatal four" list (Bureau of Labor Statistics, 2016).

It is important to mention that the risk factor affects all workers in the construction sector, although older workers are more prone to fatal accidents than young workers (with an average age of 35 years old), where according to Lipscomb et al. (2003), fatal injuries and time of work lost in construction trades continue to rank among the highest in the United States. On the other hand, according to Kisner & Fosbroke (1994), the rate of workday lost in construction was 10.1 per 100 full-time workers during the 80s in the United States, which was almost 2.5 times the rate of occupational injuries for all industries combined. In addition, the construction industry had an overall mortality rate of 25.6 per 100,000 full-time workers, so this rate was more than 3.5 times the occupational mortality rate for all industries in the United States during the same period. Falls from the same level, contact with cutting material, struck by object or crashes, and caught-in/between or crushing due to collapse or landslide expand the list of risks. Schoenfisch et al. (2010) presented similar results by pointing out that these same risks associated with more common nonfatal injuries in construction represent more than 50% of accidents being in some cases of extreme gravity.

Another important aspect to consider is construction workers' physical overexertion when doing their work. Even if it is not a cause of death, it does derive in a type of important injury called musculoskeletal disorder (MSD), a problem that affects the back mainly, provoking permanent injuries in workers in the long run, in a percentage between 60% and 90% (OSHA, 2011). Summarizing, nearly 50% of the risks of construction workers is associated to efforts, postures or movements (INSHT, 2009).

There are three types of main overexertion: a) manual handling of loads, which corresponds to lifting from the ground and moving the load to the desired location; b) static or forced posture which implies work at ground level or above shoulder level and; c) repetitive movements (Waters et al., 1994; INSHT, 2003; Piedrabuena et al., 2008). Regarding these types of injuries, older workers complain about uncomfortable postures, although they have fewer injuries than younger workers do (Hoonakker & van Duivenbooden, 2010). The recurrent symptoms appear in the back, neck and knee due to uncomfortable positions and working in the same position during long periods (Rosecrance et al., 1996). These results are similar to Merlino et al. (2003) who identify the lower back, wrist and knee as the most affected parts of the body due to kneeling, leaning and standing work. Most of these pathologies are not produced by accident, but because of small and repetitive injuries. Some of these simple movements such as lifting, carrying, reaching or pushing are repeated even as much as 25,000 times per day (INSHT, 2009), mainly affecting carpenters, bricklayers (Lemasters et al., 1998) and rebar workers (Piedrabuena et al., 2008).

Finally, exposure to physical and chemical agents is mentioned as a relevant risk in construction as 80% of workers perform their work between 10 a.m. and 4 p.m. which is the period of the day with the highest U.V. radiation index, and 60% perform their daily work outdoors (Duffy et al., 2012). Outdoor workers have a higher probability of getting skin cancer because their exposure to U.V rays is cumulative; however, one of the reasons not to use sunscreen is the lack of awareness about the risks associated to sunburn, and the low perception of the benefits associated to considering this risk (Glanz et al., 2007). On the other hand, 40% of workers are exposed to levels of noise, which are higher than 85 dBA at least seven hours per day; this is enough to cause hearing loss (Neitzel et al., 2011). This, due to the operation of equipment such as the jackhammer, saw, graders and backhoes, which produce an average level of noise between 84 and 99 dBA (Legris & Poulin, 1998). In this sense, hearing loss and Tinnitus –perception of noise and ringing in ears and head as a result of noise exposure– in older workers, has become a risk factor due to the difficulty to hear the warnings from safety officers (Hallam et al., 2004). Regarding chemical agents, it should be said that 20% of workers are exposed in their workplace to airborne dust, smoke from diesel engines, and gases emitted by the welding process. This, added to the high index of smokers in construction sites, has a negative impact in respiratory diseases and cancer rates as well as dermatitis and allergies (Stern & Harin-Sweeney, 1997; Wang, 1999; Woskie et al., 2002).

Thus, in order to determine how the causes previously presented have been addressed internationally in literature, a summary that classifies accidents, physical overexertion and exposure to physical and chemical agents, considering several authors, has been developed (Tables 1 and 2). By doing this, it was possible to determine the main causes of risk which are present in the construction industry, and which have been used in this study.

**Table 1.** Bibliographic summary of risks related to accidents and physical overexertion. Source: Self elaboration.

| Risks \ Author | Lipscomb *et al.* (2003) | Bureau of Labor Statistics (2016) | Kemmlert & Lundholm (2001) | INSHT (2010) | JICOSH (2001) | Schoenfisch *et al.* (2010) | Larsson & Field (2002) | Colantonio *et al.* (2009) | Jackson & Loomis (2002) | Cruz *et al.* (2009) | Janicak (2008) | Kisner & Fosbroke (1994) | Glazner *et al.* (2005) | Piedrabuena *et al.* (2008) | INSHT (2003, 2010) | INSHT (2015) | Moore & Garg (1998) | Waters *et al.* (1994) | Colombini (2002) | OSHA (2004, 2011) | Hignett & McAtamney (2000) | Hoonakker & van Duivenbooden (2010) | Lemasters *et al.* (1998) | Welch *et al.* (2010) | Rosecrance *et al.* (1996) | Merlino *et al.* (2003) | Forde *et al.* (2005) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ACCIDENTS | | | | | | | | | | | | | OVEREXERTION | | | | | | | | | | | | | |
| Falls from different level | ● | ● | ● | ● | ● | | ● | ● | ● | ● | | ● | ● | | | | | | | | | | | | | | |
| Falls at same level | ● | | ● | ● | ● | | | ● | | ● | | ● | ● | | | | | | | | | | | | | | |
| Dropped objects | | ● | | ● | ● | ● | ● | ● | | ● | | | ● | | | | | | | | | | | | | | |
| Strucks by or against objects | ● | ● | | ● | ● | ● | | ● | | ● | | ● | ● | | | | | | | | | | | | | | |
| Contact with cutting agent | ● | ● | | ● | ● | ● | | | | ● | | ● | ● | | | | | | | | | | | | | | |
| Caught-in/between | | ● | | ● | ● | ● | | | | ● | | | ● | | | | | | | | | | | | | | |
| Electrocution | | ● | | ● | ● | | | | ● | ● | ● | ● | ● | | | | | | | | | | | | | | |
| Handling load | | | | | | | | | | | | | | ● | ● | | | ● | | ● | ● | | | ● | | | ● |
| Forced posture | | | | | | | | | | | | | | ● | ● | | | | | ● | | ● | ● | ● | ● | ● | ● |
| Repetitive movement | | | | | | | | | | | | | | ● | ● | ● | ● | | ● | ● | | | ● | ● | | | ● |

**Table 2.** Bibliographic summary of risks related to exposure to physical and chemical agents. Source: Self elaboration.

| Author / Risks | Glanz *et al.* (2007) | Duffy *et al.* (2012) | Håkansson *et al.* (2001) | Legris & Poulin (1998) | Neitzel *et al.* (2011) | Kerr *et al.* (2002) | Arezes & Miguel (2008) | Dement *et al.* (2005) | Saraiya *et al.* (2002) | Hallam et al. (2004) | Chau *et al.* (2004) | Flaspoler *et al.* (2005) | INSHT (2010) | Stern & Haring-Sweeney (1997) | Wang (1999) | Järvholm & Silverman (2003) | Spee *et al.* (2006) | Woskie *et al.* (2002) | INSHT (2015) | Bakke *et al.* (2001) | IARC (2016) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EXPOSURE TO PHYSICAL AND CHEMICAL AGENTS | | | | | | | | | | | | | | | | | | | | | |
| Exposure to noise levels | | | | • | • | • | • | • | | | | • | • | | | | | | | | |
| U.V. rays exposure | • | • | • | | | | | | • | | • | • | • | | | | | | | | |
| Airborne dust exposure | | | | | | | | | | | | | | • | • | • | • | • | • | • | • |

## Perception of Risk

Defining perception of risk is a complex task, which is independent of nationality (Martinez-Fiestas et al., 2017). The perception of risk creates many uncertainties, and is always looking for an explanation (Sjöberg, 2000). Hallowell (2010) defines perceived risk as the subjective judgment that a person makes with respect to the frequency and severity of a particular risk. On the other hand, Rundmo (2000) argues that perception of risk is composed of a subjective evaluation of the probability of experiencing an accident or illness caused by exposure to a risk.

As previously mentioned, one of the challenges regarding prevention in the construction sector is analyzing the risk perceived by workers since this has an impact in the behavior of the workers to face risks (Slovic, 2016). In addition, this determines their behavior in terms of self-protection (Vaughan, 1993). Most authors determine that the perception of risk is composed of the probability of a negative event happening and the magnitude of the consequence of such event (Drottz-Sjöberg, 1991). However, it has been debated that only these two dimensions are the ones that explain the perception of risk (Ferrer & Klein, 2015). In this sense, Aven (2007) recommends that risk not be studied only through the analysis of damage probability and its consequences, as authors such as Fischhoff et al. (1978) or Slovic et al. (1986), visualized the perceived risk as a social construct which is hard to define, and it is characterized for being multidimensional. This on the premise that risk is subjective and quantifiable through a psychometric scaling (Slovic, 1992), but it must be contextualized for every specific risk (Gierlach et al., 2010). Thus, the different risk dimensions presented by Fischhoff et al. (1978) are born as psychosocial attributes or dimension that develop a global idea from certain qualities.

As mentioned by Rodríguez-Garzón et al. (2015), attributes that consider the labor context have been based on the work conducted by Fischhoff et al. (1978) and adapted by Portell & Solé (2001). These attributes have been used in similar studies by authors such as Bronfman & Cifuentes (2003), Rodríguez-Garzón et al. (2013, 2015, 2016), and Portell et al. (2014), and according to the authors of the present research, such attributes can be classified as follows (in comparison with Rodríguez-Garzón et al. (2013), attributes related to Control of Fatality and Control of Damage have been condensed into only one attribute called Control Possibility): (1) Gravity of the consequences; (2) Immediacy of the consequences; (3) Fear; (4) Vulnerability; (5) the worker's self-knowledge; (6) Knowledge of safety officers; (7) Control Possibility; (8) Catastrophic potential (that which can affect many people at the same time.)

Each attribute mentioned before explores a characteristic of risk (Slovic et al., 1982). This way, for example, one of the attributes more closely related to the perception of risk is fear. It is evident that fear perception is high in activities which are considered dangerous by workers (Slovic et al., 1982). In addition, Rodríguez-Garzón et al. (2015) found that the most relevant attribute when evaluating perception of risk is immediacy of the consequences. On the other hand, many times workers believe that they can control or prevent risk; however, adopting unsafe practices like working faster to earn more money, provokes a lower perception of benefits associated with control or prevention (Mullen, 2004). This lack of control or prevention unconsciously causes a greater exposure to risk.

In consequence, the perception of risk is a process where a series of psychosocial attributes is at stake, with a scope that goes beyond just considering the probability of occurrence and the gravity of the consequences of a negative event.

On the other hand, sociodemographic variables when studying a perceived risk are of great importance. Age, experience, educational level and the type of trade have an impact in the gravity of the accident (Burdorf et al., 2007; López et al., 2008). In this sense, the age of the worker is a relevant aspect as workers between 18 and 35 years old are more likely to suffer accidents due to lack of experience and awareness when facing risks (European Agency for Safety & Health at Work, 2007). Zimolong & Trimpop (1998) state that nearly 85% of risks are perceived due to the workers' experience and their development. In addition, because each group of workers intervenes in very different processes, the probability of having a certain type of accident varies according to the job of the worker (Chau et al., 2004).

Finally, it should be noted that according to the studies of Fischhoff et al. (1978) and Siegrist (2000), perceived social risk correlates inversely with the perceived social benefit. In addition, the acceptability of a risk was negatively correlated with the perceived social risk and positively with the perceived social benefit. This could imply that the perceived risk can be reduced by identifying and emphasizing its benefits. However, as argued by Siegrist (2000), the correlations observed between perceived benefits and perceived risks do not imply a causal relationship between those two variables. In contrast, risk and benefit may be influenced by a third variable, which is "social trust" as a possible candidate. These authors found strong correlations between social trust and risk and the benefits judged, especially for unknown risks, with social trust having a positive influence on perceived benefit and a negative influence on perceived risk. On the other hand, a study by Alhakami & Slovic (1994) suggested that risk and benefit could be inversely related in the minds of people, due to the effect of evaluating the risk or benefit of a specific hazard. That is why it is essential to characterize the perception of risk, based on the psychometric paradigm as analyzed in a study of the construction industry in Chile by Bronfman & Cifuentes (2013).

## Methodology

According to Portell et al. (2014), to understand how workers perceive risk is important for effective communication of risks and risk management, being essential to adapt the key elements of the psychometric approach to characterize the perception of occupational risk at the worker level, which allows capturing how workers perceive hazards in their immediate work environment.

In order to address the topic in question, a survey was taken as measuring instrument because it is the most common tool for perception of risk studies (Sjöberg, 1998) and also suggested by Portell & Sollé (2001). For this, a questionnaire with the 8 attributes mentioned before and the 13 risks identified through the bibliographic revision was created.

The questions were developed according to the standard set by Portell & Solé (2001) at the document Perceived risk: an assessment procedure conducted by the Instituto Nacional de Seguridad e Higiene en el Trabajo in Spain (INSHT, 2015) and adapted to Borg's scale (1982). This allowed perception to be measured in a point-scale from one to ten points.

This allowed perception to be measured in a scale from one to ten points. Consequently, for each one of the eight attributes, each worker was asked to answer according to the structure shown in Figure 1.

**Figure 1.** Survey Applied for Study. Source: Self elaboration.

Age: Education:
Occupation / Trade: Years in the field:

Respond perception in scale 1 to 10

| RISKS / ATTRIBUTES | Fall from height | Fall at same level | Dropped objects | Struck by objects by or against | Cuts | Caught-in/between | Electrocution | Lifting and carrying load | Forced postures | Repetitive Movements | Noise exposure | Sun exposure | Airborne dust exposure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gravity of consequences | | | | | | | | | | | | | |
| Immediacy of consequences | | | | | | | | | | | | | |
| Knowledge of workers | | | | | | | | | | | | | |
| Knowledge of safety officer | | | | | | | | | | | | | |
| Fear | | | | | | | | | | | | | |
| Probability | | | | | | | | | | | | | |
| Catastrophic Potential | | | | | | | | | | | | | |
| Control Possibility | | | | | | | | | | | | | |

Data collection was performed by randomly selecting a sample of 137 workers from a universe of workers considered for the selection of 450 located in construction sites in the south of Chile. This sample approximately represents 30% of the total, considered valid of this type of studies in construction (Chinowsky, 2001; Forcael *et al.*, 2017). Some of the jobs considered in the sample are: rebar workers, bricklayers, carpenters, scaffolders, laborers and machinery operators, whose distribution is shown in Table 3.

**Table 3.** Distribution of the sample. Source: Self elaboration.

| Sociodemographic Variable | N° Workers | (%) |
|---|---|---|
| Job | | |
| Carpenters | 40 | 29 |
| Rebar workers | 25 | 19 |
| Scaffolders | 15 | 11 |
| Concrete workers and bricklayers | 21 | 15 |
| Laborers | 30 | 22 |
| Operators and rigger | 6 | 4 |
| Age Range | | |
| <35 | 73 | 53 |
| Between 35 and 45 | 40 | 29 |
| >45 | 24 | 18 |
| Work Experience | | |
| <10 years | 70 | 51 |
| Between 10 and 15 years | 28 | 21 |
| >15 years | 39 | 28 |
| Level of Education | | |
| Incomplete High School | 59 | 43 |
| Complete High School | 72 | 53 |
| Incomplete University/Technical | 6 | 4 |

## Results and discussion

### Validation of the Survey

To validate the measuring instrument used, a validity and reliability analysis was performed, based on the fact that such instrument measures what it is really wanted to be measured, and on the other hand its reliability, understood as the absence of random errors and independence of deviations produced by causal errors (Sivo et al., 2006; Escobar-Pérez, 2008; Sampieri et al., 2010).

**Content Validity**

Because the measuring instrument intends to evaluate risk perception, first a thorough bibliographical review of studies and publications was performed. This allowed the thirteen risks selected for the survey to be supported. Finally, the instrument was also validated by the expert opinion from specialist professionals and scholars (Escobar-Pérez, 2008; Forcael et al., 2012; González et al., 2015), in the field of construction and risk prevention.

**Construct Validity**

To validate the construct, the technique of factor analysis was used. This was performed for all attributes meeting the following parameters and being presented in Table 4.

- N= 137 > 50 interviews (De la Garza et al., 2013)
- Kayser – Meyer – Olkin Test (KMO) > 0.5 (Hair et al., 1995; Vivanco, 1999; Tabachnick & Fidell, 2007).
- Bartlett's Sphericity Contrast: < 5% significance (Vivanco, 1999).

***Reliability of the Sample***

The test performed showed a level of dependability that allows guaranteeing the reliability for each attribute (α > 0.7) according to the Cronbach criterion (Cronbach, 1949) as shown in Table 5.

**Table 4.** Construct Validity. Source: Self elaboration.

| Attribute | KMO Test | Bartlett Test |
|---|---|---|
| Gravity of the consequences | 0.811 | 0.000 |
| Immediacy of the consequences | 0.819 | 0.000 |
| Fear | 0.862 | 0.000 |
| Vulnerability | 0.796 | 0.000 |
| Knowledge of the safety officer | 0.547 | 0.000 |
| Control Possibility | 0.868 | 0.000 |
| Catastrophic Potential | 0.801 | 0.000 |

**Table 5.** Reliability of the Sample. Source: Self elaboration.

| Attribute | Alfa Cronbach (α) |
|---|---|
| Gravity of the consequences | 0.869 |
| Immediacy of the consequences | 0.878 |
| Fear | 0.913 |
| Vulnerability | 0.895 |
| Self-knowledge of the worker | 0.997 |
| Knowledge of the safety officer | 0.989 |
| Control Possibility | 0.945 |
| Catastrophic Potential | 0.801 |

**Perceived Risk Analysis**

***Perceived Risk Quantification***

With the information collected, a perceived risk analysis was performed based on the workers under study. The treatment of these data was carried out through a statistical analysis with attributes of the psychometric paradigm $A_j$ (with j=1 to 8) and of the risks $R_i$ (with i=1 to 13). In Table 6, the categorization given to each of them is presented.

**Table 6.** Attributes and explored risks. Source: Self elaboration.

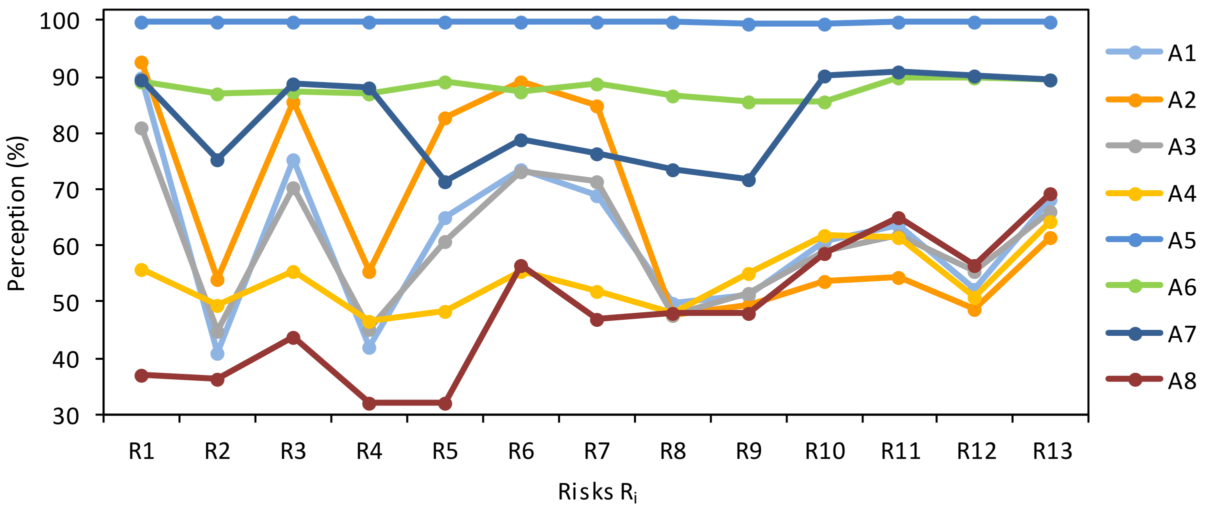
| Attributes ($A_j$) | Risks ($R_i$) |
|---|---|
| $A_1$: Gravity of the consequences | $R_1$: Fall from different level |
| $A_2$: Immediacy of the consequences | $R_2$: Fall at the same level |
| $A_3$: Fear | $R_3$: Dropped objects |
| $A_4$: Vulnerability | $R_4$: Struck by objects/crashes |
| $A_5$: Self-knowledge of the worker | $R_5$: Cuts |
| $A_6$: Knowledge of sec. manager | $R_6$: Caught-in/between |
| $A_7$: Control Possibility | $R_7$: Electrocution |
| $A_8$: Catastrophic potential | $R_8$: Manual handling load |
| | $R_9$: Forced posture |
| | $R_{10}$: Repetitive movement |
| | $R_{11}$: Noise exposure |
| | $R_{12}$: U.V. rays exposure |
| | $R_{13}$: Airborne dust exposure |

The results of the survey initially in a scale from 1 to 10 points were transformed to a scale of 0 to 100%. Data analysis allowed obtaining the results shown in Table 7 and in Figure 2, where average meaning values $\bar{A}_j$ were obtained for each attribute $A_j$ in respect to each risk $R_i$.

**Table 7.** Average obtained for each risk. Source: Self elaboration.

| | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ | $R_6$ | $R_7$ | $R_8$ | $R_9$ | $R_{10}$ | $R_{11}$ | $R_{12}$ | $R_{13}$ | $\bar{A}_j$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 89.9 | 41.0 | 75.2 | 42.0 | 65.0 | 73.4 | 68.8 | 49.9 | 51.1 | 60.9 | 63.7 | 52.3 | 68.1 | **61.6** |
| $A_2$ | 92.6 | 54.0 | 85.6 | 55.3 | 82.8 | 89.1 | 84.9 | 47.5 | 49.6 | 53.7 | 54.3 | 48.8 | 61.5 | **66.1** |
| $A_3$ | 81.0 | 44.8 | 70.2 | 45.2 | 60.7 | 73.1 | 71.5 | 47.8 | 51.5 | 59.1 | 61.8 | 55.4 | 66.2 | **60.6** |
| $A_4$ | 55.7 | 49.6 | 55.3 | 46.6 | 48.5 | 55.4 | 51.9 | 47.9 | 55.0 | 61.9 | 61.6 | 51.0 | 64.4 | **54.2** |
| $A_5$ | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.7 | 99.6 | 99.6 | 99.8 | 99.8 | 99.8 | **99.7** |
| $A_6$ | 89.0 | 87.1 | 87.4 | 87.0 | 89.2 | 87.5 | 88.7 | 86.6 | 85.7 | 85.6 | 89.8 | 89.9 | 89.4 | **87.9** |
| $A_7$ | 89.4 | 75.3 | 88.7 | 88.2 | 71.5 | 78.8 | 76.5 | 73.5 | 71.8 | 90.4 | 90.9 | 90.1 | 89.4 | **82.6** |
| $A_8$ | 37.1 | 36.2 | 43.9 | 32.0 | 31.9 | 56.5 | 46.9 | 47.9 | 48.0 | 58.8 | 65.1 | 56.6 | 69.2 | **48.5** |

**Figure 2.** Average obtained for $R_i$, risks for each $A_j$ attribute. Source: Self elaboration.



In order to perform the results analysis, the risk perceived was classified in a Likert-type scale of 5 points, as shown in Table 8.

**Table 8.** Classification of perceived Likert-scale-type risk. Source: Self elaboration.

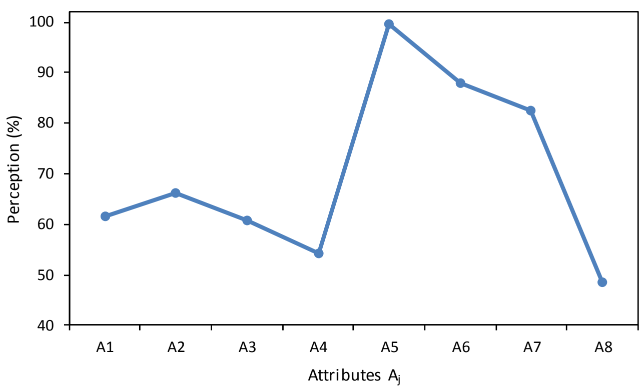
| Level of perception (%) | Classification |
|---|---|
| 0 – 20 | Very low |
| 20 – 40 | Low |
| 40 – 60 | Medium |
| 60 – 80 | High |
| 80 – 100 | Very high |

Thus, taking into consideration Likert's classification in Table 8 and according to Figure 2, it is observed that, in general, workers consider a very high level of self-knowledge for all risks ($A_5$); that perceive as very grave ($A_1$) a fall from height ($R_1$). In addition, they perceive immediate health consequences ($A_2$) for this risk and for other risks with high fatality rate, such as dropped objects ($R_3$), caught-in/between ($R_6$) and electrocution ($R_7$). Specifically regarding Figure 2, it is observed that for attributes $A_1$ (Gravity), $A_2$ (Immediacy of consequences), $A_3$ (Fear), $A_4$ (Vulnerability) and $A_8$ (Catastrophic Potential), workers show a similar level of perception compared to the risks associated to physical overexertion ($R_{8\text{-}9\text{-}10}$), exposure to noise levels ($R_{11}$), sun ($R_{12}$) and airborne dust ($R_{13}$). It should be emphasized that for the last risks shown in Figure 2 ($R_8$ to $R_{13}$, i.e. from manual handling load to airborne dust exposure), the values of $A_2$ (Immediacy of consequences) decrease because the consequences of the exposure to such risks often appear many years after the first exposure.

***Profile of the construction worker in building construction according to the attributes of risk perception***

Considering the average obtained per attribute ($\bar{A}_j$ of Table 7) observed in Figure 3, it can be concluded that the construction worker in building believes that he possesses a very high level of self-knowledge of the evaluated risks ($A_5$ = 99.7%). It is also observed that even though a high value was assigned to the knowledge of the safety officers at the construction site ($A_6$ = 87.9%) they consider that it is lower than the one they have. Also, the high value assigned to attribute 7 is outstanding, that is to say that it is considered that in average, they have a high capacity of control over different risks ($A_7$ = 82.6%). On the other hand, they are aware of the fact that an accident happening in their work is grave ($A_1$ = 61.6%), and the consequences of the damage that can happen are immediate ($A_2$ = 66.1%). However, they feel moderately vulnerable to construction risks ($A_4$ = 54.2%), and they show a level of fear higher than the average regarding the occurrence of the accident ($A_3$ = 60.6%).

**Figure 3.** Average obtained per attributes for all the risks. Source: Self elaboration.




## Analysis of the Incidence of Sociodemographic Variables in Perceived Risk

***Starting point assumptions***

The assumptions to start the incidence analysis were the following: 1) The statistical treatment of the data showed that Kolmogorov-Smirnov's normality test is rejected for all the attributes in question because the significance level was lower than 0.05 in all cases. 2) Due to the fact that the distribution of the job variables, age range and work experience presented three or more independent samples, a statistical analysis was performed, not a parametric one with the Kruskal-Wallis comparative test (Siegel et al., 1972); 3) In the case of the distribution of the variable educational level of the workers, due to the fact that only 2 independent subsamples were representative, the Mann-Whitney U test was applied for that case (Siegel et al., 1972).

***Incidence of the occupation variable***

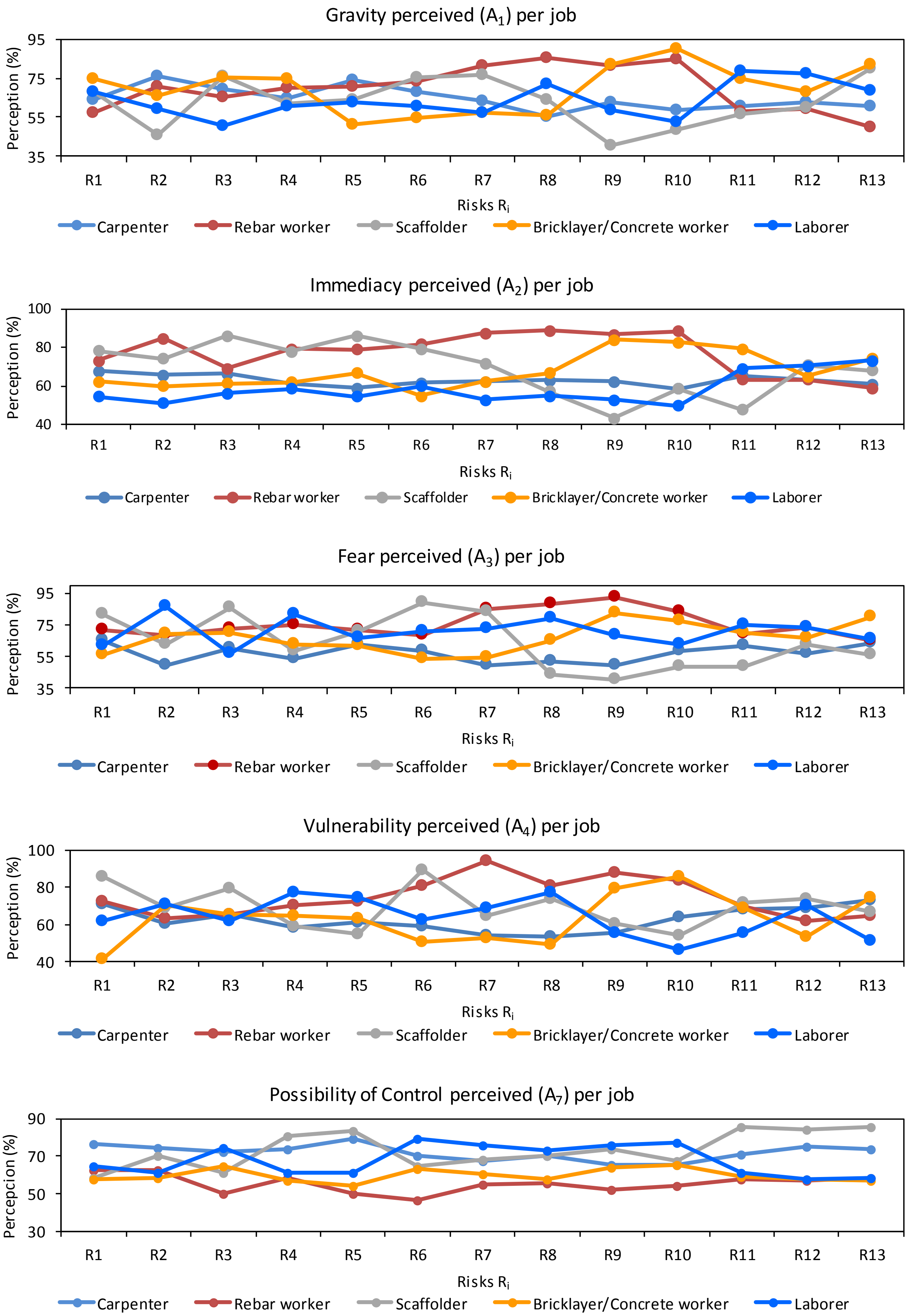
In Table 9 the results of the Kruskal-Wallis test are shown where statistically significant differences of risk perception exist ($p < 0.05$), in relation to the worker's trade: $G_1$: Carpenters; $G_2$: Rebar workers; $G_3$: Scaffolders; $G_4$: Bricklayers and Concrete workers; $G_5$: Day laborers. When making the statistical analysis it was shown that the occupations of machinery operator and rigger did not affect the results due to its low number (only 4%), which is why they were excluded from the sample.

Meanwhile in Figure 4 the attributes and risks mentioned in Table 9 are observed, where workers showed statistically significant differences of risk perception.

**Table 9.** Results of the Kruskal-Wallis test for occupation variable. Source: Self elaboration.

| Risks | p-value | Significant difference of perception |
|---|---|---|
| $A_1$ Gravity of consequences | | |
| $R_8$: Manual handling of load | 0.014 | $G_2>G_1$ |
| $R_9$: Forced/static posture | 0.003 | $G_2>G_3$ y $G_4>G_3$ |
| $R_{10}$: Repetitive movement | 0.000 | $G_4>G_1$, $G_2>G_3$, $G_2>G_5$,$G_4>G_3$, $G_4>G_5$ |
| $R_{13}$: Dust exposure | 0.020 | $G_4>G_2$ |
| $A_2$ Immediacy of consequences | | |
| $R_2$: Fall at same level | 0.011 | $G_2>G_5$ |
| $R_7$: Electrocution | 0.006 | $G_2>G_5$ |
| $R_8$: Manual handling of load | 0.008 | $G_2>G_5$ |
| R9: Forced posture | 0.000 | $G_2>G_3$, $G_2>G_5$, $G_4>G_3$, $G_4>G_5$ |
| $R_{10}$: Repetitive movement | 0.000 | $G_2>G_1$, $G_2>G_5$, $G_4>G_5$ |
| $A_3$ Fear | | |
| $R_2$: Fall at same level | 0.001 | $G_5>G_1$ |
| $R_4$: Struck by objects | 0.013 | $G_5>G_1$ |
| $R_7$: Electrocution | 0.000 | $G_2>G_1$, $G_3>G_1$ |
| $R_8$: Manual handling of load | 0.000 | $G_2>G_1$, $G_5>G_1$, $G_2>G_3$, $G_5>G_3$ |
| $R_9$: Forced posture | 0.000 | $G_2>G_1$, $G_4>G_1$, $G_2>G_3$, $G_4>G_3$ |
| $A_4$ Vulnerability | | |
| $R_2$: Fall from different level | 0.002 | $G_1>G_4$, $G_3>G_4$ |
| $R_6$: Caught-in/between | 0.001 | $G_3>G_4$ |
| $R_7$: Electrocution | 0.000 | $G_2>G_1$, $G_2>G_4$ |
| $R_8$: Manual handling of load | 0.001 | $G_2>G_1$, $G_2>G_4$ |
| $R_9$: Forced posture | 0.000 | $G_2>G_1$, $G_2>G_5$ |
| $R_{10}$: Repetitive movement | 0.000 | $G_2>G_5$, $G_4>G_5$ |
| $A_7$ Possibility of Control | | |
| $R_5$. Cuts | 0.001 | $G_1>G_2$ |
| $R_6$: Caught-in/between | 0.018 | $G_5>G_2$ |

**Figure 4.** Attributes with significant differences in the perception of each risk per job. Source: Self elaboration.



According to Figure 4, the group that corresponds to rebar workers ($G_2$) and bricklayers and concrete workers ($G_4$) perceive a graver and faster damage to health in relation to works that need repetitive movements ($R_{10}$). Similarly, rebar workers ($G_2$), express a very high fear and vulnerability in activities related to physical overexertion ($R_{8-9-10}$) and electrocution ($R_7$). On the other hand, day laborers ($G_5$) perceive the possibility of controlling or preventing an entrapment much more ($R_6$), while the corresponding group of scaffolders ($G_3$), consider the possibility of preventing cuts very high ($R_5$).

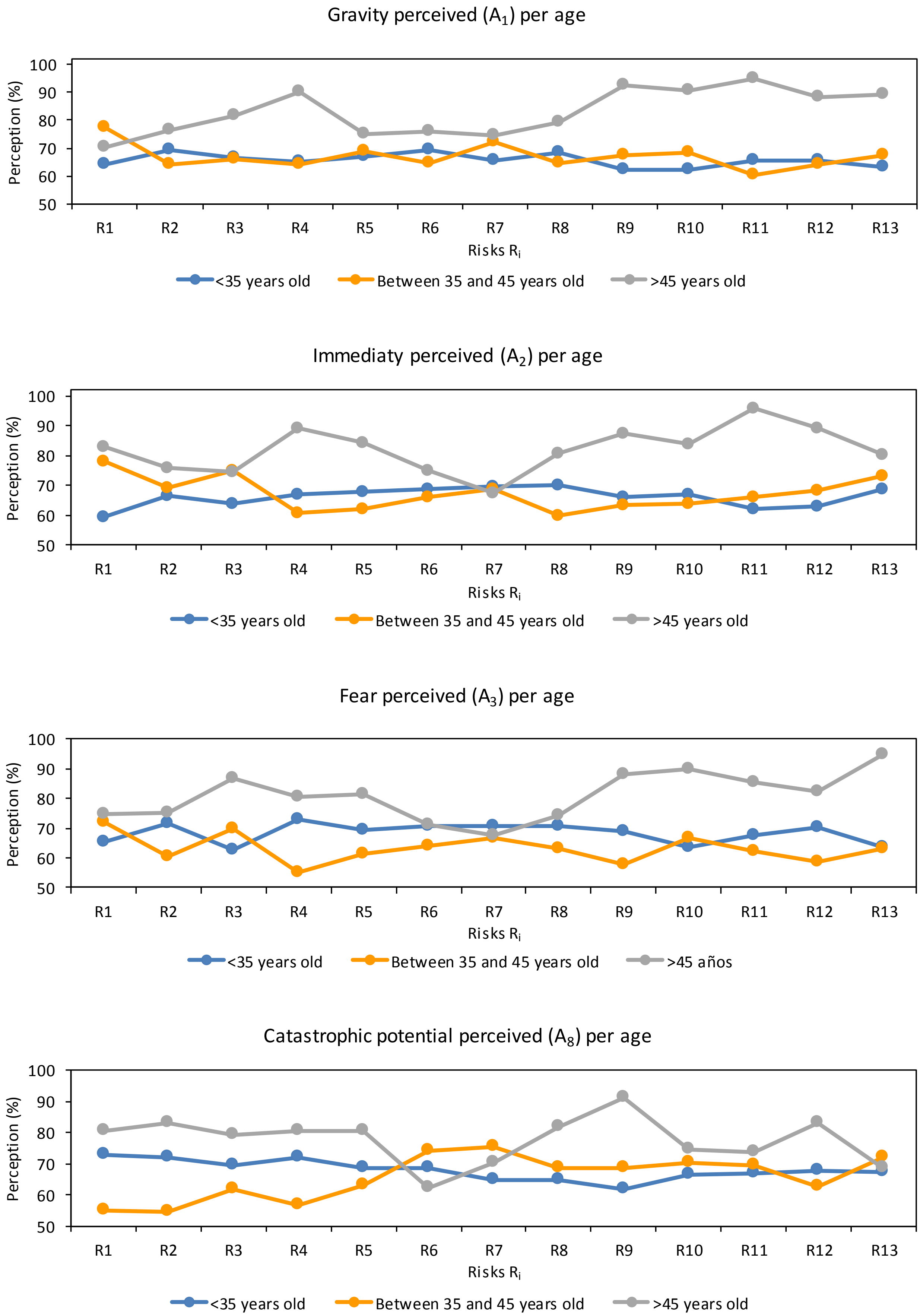
***Incidence of the Age Variable***

In Table 10 are presented the results of the Kruskal-Wallis test where there are statistically significant differences of risk perception ($p < 0.05$), in relation to the age of the worker. $G_1$: younger than 35 years old; $G_2$: between 35 and 45 years old; $G_3$: older than 45 years old.

**Table 10.** Results of the Kruskal-Wallis test for age variable. Source: Self elaboration.

| Risks | p-value | Significant differences of perception |
|---|---|---|
| $A_1$ Gravity of the consequences | | |
| $R_4$: Struck | 0.014 | $G_3>G_1$, $G_3>G_2$ |
| $R_9$: Forced posture | 0.004 | $G_3>G_1$, $G_3>G_2$ |
| $R_{10}$: Repetitive Movement | 0.008 | $G_3>G_1$ |
| $R_{11}$: Noise exposure | 0.001 | $G_3>G_1$, $G_3>G_2$ |
| $R_{12}$: U.V. rays exposure | 0.026 | $G_3>G_1$ |
| $R_{13}$: Dust exposure | 0.016 | $G_3>G_1$ |
| $A_2$ Immediacy of the consequences | | |
| $R_1$: Falls from a different level | 0.002 | $G_2>G_1$, $G_3>G_1$ |
| $R_4$: Struck | 0.015 | $G_3>G_2$ |
| $R_{11}$: Noise exposure | 0.001 | $G_3>G_1$, $G_3>G_2$ |
| $R_{12}$: U.V. rays. Exposure | 0.013 | $G_3>G_1$ |
| $A_3$ Fear | | |
| $R_3$: Dropped objects | 0.028 | $G_3>G_1$ |
| $R_4$: Struck by objects | 0.019 | $G_3>G_2$ |
| $R_9$: Forced posture | 0.010 | $G_3>G_2$ |
| $R_{10}$: Repetitive movement | 0.012 | $G_3>G_1$ |
| $R_{13}$: Dust exposure | 0.001 | $G_3>G_1$, $G_3>G_2$ |
| $A_8$ Catastrophic potential | | |
| $R_1$: Fall from a different level | 0.014 | $G_3>G_2$ |
| $R_2$: Fall at same level | 0.008 | $G_3>G_2$ |
| $R_9$: Forced posture | 0.003 | $G_3>G_1$ |

**Figure 5.** Attributes with significant differences in the perception of each risk per age. Source: Self elaboration.



In relation to Figure 5, it can be observed that workers older than 45 years old ($G_3$) perceive a significantly more severe and immediate damage compared to the exposure to high levels of noise ($R_{11}$) in relation to younger workers. In addition, they express a bigger fear to airborne dust exposure ($R_{13}$). Moreover, they consider that works that require uncomfortable or forced postures ($R_9$), are a considerable catastrophic potential that can affect many workers at the same time.

***Incidence of the Work Experience Variable***

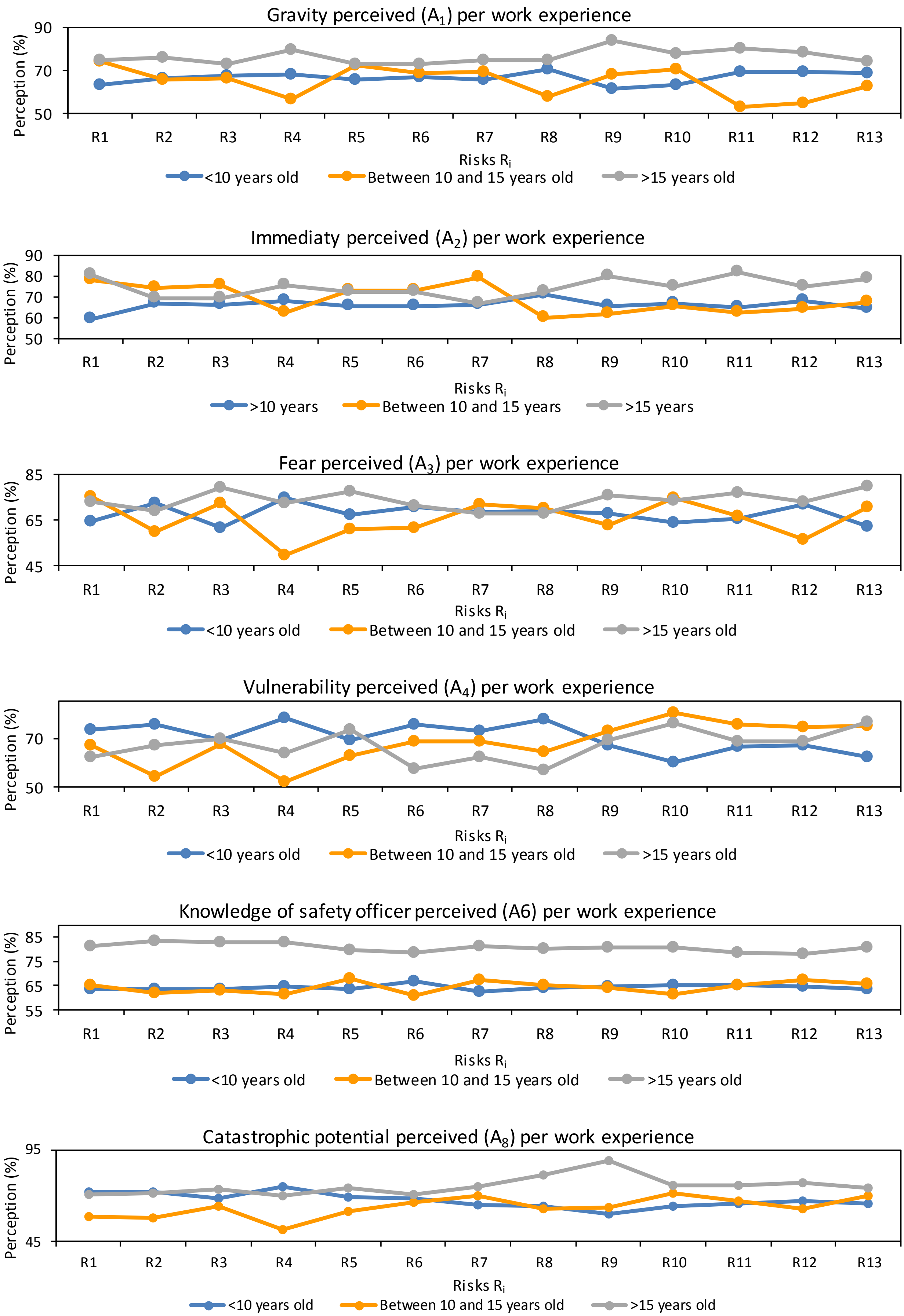
In Table 11, the results of the Kruskal-Wallis test are presented. There are statistically significant differences of risk perception ($p < 0.05$), in relation to the worker's work experience where $G_1$: less than 10 years; $G_2$: between 10 and 15 years; $G_3$: more than 15 years.

**Table 11.** Results of the Kruskal-Wallis test for the experience variable. Source: Self elaboration.

| Risks | p-value | Significant difference of Perception |
|---|---|---|
| $A_1$ Gravity of the consequences | | |
| $R_9$: Forced postures | 0.016 | $G_3>G_1$ |
| $R_{11}$: Noise exposure | 0.019 | $G_3>G_2$ |
| $R_{12}$: U.V. rays exposure | 0.040 | $G_3>G_2$ |
| $A_2$ Immediacy of the consequences | | |
| $R_1$: Fall from a different level | 0.003 | $G_3>G_1$ |
| $A_3$ Fear | | |
| $R_4$: Struck by object | 0.013 | $G_1>G_2$ |
| $A_4$ Vulnerability | | |
| $R_4$: Struck by object | 0.002 | $G_1>G_2$ |
| $R_8$: Manual handling of load | 0.016 | $G_1>G_3$ |
| $A_6$ Knowledge of Safety Officer | | |
| $R_2$: Falls at same level | 0.016 | $G_3>G_1$ |
| $A_8$ Catastrophic potential | | |
| $R_4$: Struck by object | 0.023 | $G_1>G_2$ |
| $R_9$: Forced posture | 0.000 | $G_3>G_1$, $G_3>G_2$ |

According to Figure 6, it can be observed that workers with the most experience ($G_3$) compared to those with less experience ($G_1$ y $G_2$) have a better perception that safety officers of construction have the adequate knowledge regarding construction's risks. In addition, they show that works related to forced and uncomfortable postures ($R_9$) constitute a relevant catastrophic potential, which can affect many workers at the same time. Workers with less experience ($G_1$) perceive a greater vulnerability regarding struck by object ($R_4$).

**Figure 6.** Attributes with significant differences in the perception of each risk by work experience. Source: Self elaboration.



### *Incidence of the Level of Education Variable*

Because 96% of workers had a level of junior high school education, to perform this part of the analysis, it was categorized in two subsamples: incomplete junior-high education and complete junior-high education. The subsample regarding incomplete university studies or incomplete technical university only represented 4% of the total sample that is why when incorporating it to the analysis was not relevant and it was excluded from the analysis.

The Mann-Whitney U test finally determined that there are no statistically significant differences in risk perception from the point of view of the worker's educational level for the evaluated level. In other words, workers with junior-high education both incomplete and complete do not perceive risk in a significantly different way.

## Conclusions

The present study aimed to evaluate the perception of risks of construction workers considering the psychometric paradigm and some sociodemographic variables. The main results after having performed the analysis allow us to conclude that:

- The risk perceived by construction workers presents similar results to that observed in other studies and previous publications. These show a very high level of perception regarding the immediacy of the consequences associated to: falls from different level, struck by object hazards, caught-in/between, and electrocution (e.g. JICOSH, 2001; Glaznerstrok et al., 2005; Cruz et al., 2009; INSHT, 2010; Bureau of Labor Statistics, 2016). These four are precisely the causes of death in the sector of construction (fatal four).

- Workers perceive a greater vulnerability regarding those risks to which they cannot avoid being exposed to, even though they perceive that they do have the possibility to prevent or control them especially repetitive movements, exposure to high levels of noise, sun exposure and airborne dust exposure. Related to these last risks, it could be posed that workers have this perception because the consequences of the exposure to such risks often appear many years after the first exposure.

- Workers older than 45 years old, compared to younger workers consider noise exposure as of extreme gravity, which might be attributed to the appearance of the first symptoms of hearing loss in them.

- The high perception shown by workers with the most experience regarding catastrophic potential that involve forced and uncomfortable postures, show important similarities regarding other international studies in this subject (e.g. OSHA, 2011; INSHT, 2015).

- Rebar workers, laborers and concrete workers perceive a damage due to physical overexertion (especially forced posture and repetitive movement), much more severe and immediate for their health compared to other trades. This is consistent with international experience, due to the greater exposure of these trades to such overexertion.

- From the analyzed data, it was possible to develop a profile for construction workers in building where their main characteristics indicate that they perceive to have a very high self-knowledge regarding the risks to which they are submitted. They show to be aware of the fact that an accident happening in their work can be serious, and the consequences of the damage may be immediate. They feel moderately vulnerable to construction risks, although they have a higher level of fear regarding the occurrence of an accident; and a very high level of awareness regarding the possibility they have to control and avoid dangerous activities. Finally, safety officers are given a very high level of knowledge at the construction site.

- It has to be noted that this research has limitations. In the first place, only workers from building construction projects working in a developing country were considered. In addition, the results cannot be totally generalized, because only workers who voluntarily wanted to respond participated, and it is probable that the results would have been different, if those workers who did not want to participate had been also included. Future research lines may include workers from other construction sectors (highways, industrial construction, tunnelling, mining works, among others).

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