

A Meta-Analysis of Crew Resource Management/Incident Command Systems Implementation Studies in the Fire and Emergency Services

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Abstract

This research is a meta-analysis of studies on Crew Resource Management (CRM)/Incident Command System implementation in the fire and emergency services. After a thorough literature review, four sets of results were analyzed to determine if CRM training was effective. An aggregate total of 283 test scores were evaluated. The data indicated that CRM training was effective in all studies analyzed. Fixed and random effects models indicated significance as well. The studies had a high degree of heterogeneity probably due to different training and testing procedures used. The data support the use of CRM training in the fire and emergency services. There is evidence for the need for ongoing CRM training as well. Recommendations include designing CRM training with both initial and recurring sessions to ensure internalization of CRM concepts. Future research should also focus on studies with course outcome measures such as pre and post test scores.

Keywords: crew resource management, incident command systems, fire, emergency services, maintenance resource management, participative leadership

Introduction

The need for using participative leadership tools such as CRM evolved from an NTSB recommendation that followed United Airlines Flight 173 crash in 1978 (Jedick, 2014). NASA, civilian and military aviation communities implemented Crew Resource Management (CRM) training to improve decisionmaking during flight operations. Maintenance Resource Management (MRM) was a variant of CRM originating in the early 1990s with airlines such as U.S. Air (McKenna, 2002). CRM was adopted by the medical community in the 1990s, specifically in the surgical and nursing areas, to prevent untoward outcomes and infections (Sundar et al., 2007). Since the mid-1990s, fire and emergency services organizations began using CRM and Incident Command Systems training to reduce human error in firefighting and prehospital care (Lubnau & Okray, 2001). This research focused on fire and emergency services studies to determine if CRM/Incident Command Systems training impact student retention of CRM concepts in a meaningful way. Meta-analysis statistical procedures were used to determine effect sizes (standardized mean differences) and levels of heterogeneity between the studies.

Significance

Lubnau and Okray (2001) argue that the idea that “Only the lead dog has a good view” is no longer acceptable in the fire service (p. 8). They further argue that leaders should use the entire team’s

skills. Citing the sentinel event of the 1994 Storm King Mountain fire where 14 fire fighters perished as a catalyst, the fire service needs to build on the CRM training successes enjoyed by aviation and medical communities. Nineteen years later, similar calls for improving firefighter CRM went out after the Yarnell fire killed 19 firefighters (Leschak, 2013). The number of fires from 2002 through 2013 have decreased from 1.68 million to 1.24 million. Firefighters have responded to 447,500 fewer fires (NFPA, 2014). Firefighter deaths have averaged around 87 per year showing a steady decline over the 12 year period, yet there is a weak correlation between number of fires and firefighter deaths ($r=.464$, $p=.128$). Approximately 78 percent of the variation between number of fires and fire fighter deaths cannot be explained simply by the number of fires. Any tool that can improve decision-making and reduce error needs to be considered (Wakeham & Griffith, 2015).

Problem Statement

The problem examined is to determine if CRM training enhances student retention of CRM principles in any meaningful way. The authors chose to do a meta-analysis to examine this problem.

Literature Review

CRM – History, Origins and Applications

Crew Resource Management (CRM) has been comprehensively defined as;

A flexible, systemic method for optimizing human performance in general, and increasing safety in particular, by (1) recognizing the inherent human factors that cause errors and the reluctance to report them, (2) recognizing that in complex, high risk endeavors, teams rather than individuals are the most effective fundamental operating units and (3) cultivating and instilling customized, sustainable and team-based tools and practices that effectively use all available resources to reduce the adverse impacts of those human factors (Marshall, 2009, p. 22).

Though common jargon in today's managerial environments, *crew resource management*, initially more narrowly referred to as *flightdeck* or *cockpit resource management*, formally began with a National Transportation Safety Board (NTSB) recommendation made during their investigation of the 1978 United Airlines Flight 173 crash. In that disaster a DC-8 crew ran out of fuel over Portland, Oregon while troubleshooting landing gear malfunction. The NTSB concluded that the crash was ultimately caused by poor team communication and the captain's failure to accept input from junior crew members combined with a lack of assertiveness by the flight engineer (Jedick, 2014).

From these conclusions, the NTSB made several recommendations in their report, including;

Issue an operations bulletin to all air carrier operations inspectors directing them to urge their assigned operators to ensure that their flightcrews are indoctrinated in principles of flightdeck resource management, with particular emphasis on the merits of participative management for captains and assertiveness training for other cockpit crewmembers (NTSB, 1978, Class II, Priority Action X-79-17).

In essence, crew resource management is a more focused and specific application of the broader concept of participative management, which grew out of the human relations movement and gained momentum through the 1960s and 1970s. Advocates of participatory management practices challenged the traditional organizational hierarchies, authoritarian systems and rigid division of labor. While this form of leadership style was acknowledged across various industries and workplace settings for empowering employees and increasing loyalty and motivation, the NTSB recognized its more crucial role in emergency situations where it could play a part in the prevention of and/or reaction during disasters, thus potentially saving lives.

After the NTSB recommendations were published, CRM training was first adopted by United Airlines in 1981 and subsequently has become a mandatory part of crew training for most major airlines, NASA and military aviation (Jedick, 2014; Marshall, 2009). In its early application, CRM training focused primarily on pilots and the immediate cockpit environment. However, with verification of its efficacy throughout the 1990s, it was extended to flight attendants and maintenance technicians, and finally for all aviation personnel (Helmreich et al., 1999).

Maintenance resource management (MRM) refers to CRM as specifically applied in an aircraft maintenance setting. Just as CRM emerged from the analysis of a preventable aviation accident, a similar mishap led to the development of MRM and maintenance-based human factors training. In 1988, Aloha Airlines Flight 243 suffered a near-catastrophic failure. The subsequent investigation identified various human-factors-related problems leading to the failed inspections that were determined to be the main cause of the mishap. These findings highlighted maintenance activities as potential accident causal factors, and thus led to the development and implementation of MRM training (Sian. Robertson & Watson, 1998). The first documented governmental regulation for standardized MRM training appeared in the Advisory Circular 120-72, Maintenance Resource Management Training in September, 2000.

In keeping with the basic tenets of CRM, MRM training emphasizes a team approach to human error reduction using principles that seek to improve communications, situational awareness, problem solving, decision making, and teamwork. MRM advocates a decentralized, human-centric approach to safety and encourages work teams to communicate vital operational risk and safety information directly and informally, regardless of rank or position, thus permitting rapid response to prevent impending crises (McKenna, 2002, Taylor, 1998).

Since its inception as a reaction to the NTSB recommendations, the role of CRM in enhancing teamwork, and thus safety, has been widely accepted (Salas, Burke & Bowers, 2001; Salas, Rhodenizer & Bowers, 2000). Marshall (2009) observed, “CRM training, coupled with consistent and routine error and incident reporting, has helped transform commercial aviation into

a model of high reliability, now operating well beyond a level of Six Sigma quality and safety” (p. 6). Marshall further noted the usefulness of applying CRM to medical settings, indicating, “It took a landmark tragedy to indelibly imprint the lesson of human fallibility and rouse of revolution in aviation safety that is now spreading to health care” (2009, p. 5).

He goes on to iterate the applicability of CRM systems in various medical settings, stating;

Aviation and health care have much in common. Both fields are extremely complex, requiring that highly trained personnel function ably under considerable stress. In both, human beings are entrusted with the safety of others, and the available literature is replete with evidence that human factors cause the vast majority of harmful mistakes (Marshall, 2009, p. 7).

Empirically, Sexton and associates (2000) compared flight crews with operating room personnel on several CRM-related measures, including attitudes and practices involving teamwork. This landmark study, conducted over a 15-year period, included more than 30,000 cockpit crew members (captains, first officers, and second officers) and 1,033 operating room personnel (attending surgeons, attending anesthesiologists, surgical residents, anesthesia residents, surgical nurses, and anesthesia nurses). Sexton and colleagues concluded that safety-related behaviors that have been applied and studied extensively in the aviation industry are also relevant in health care. Various other researchers (Gaba, et al., 2001; Howard, 1992; Risser, 1999 & Shortell, 1994) reached similar conclusions on the relative applicability of CRM training approaches in medical context where human factors play a large role.

CRM in Emergency Services

As with the aforementioned medical environments, similarities exist between crew interaction in aviation settings (particularly in response to emergency situations) and the interactions of emergency service crews. Specifically, the following comparisons can be drawn: 1) Both crews are structured with a leader and one or more crew members; 2) The group functions best when it works as a cohesive team; 3) The team can spend hours of time performing mundane activities and then be called upon to act swiftly under stressful conditions; and 4) Some crews work together frequently and others are assembled on short notice (Tippett, 2009). Additionally, as in aviation and medical emergency situations, factors such as severe time pressure, personal danger, loud noise, multiple distractions and a confusing and dynamically changing environment further complicate the situation and exacerbate the need for effective and efficient teamwork (LeSage, Dyar, & Evans, 2011).

Furthermore, like in aviation, communication failures, poor decision making, lack of situational awareness, poor task allocation and leadership failures are listed as the contributing factors in far too many National Institute of Occupational Safety and Health (NIOSH) Firefighter Line-of-Duty Death Reports (IAFC, 2005). Despite advances in fire service equipment, standards and education that have substantially reduced the number of fires and enhanced the firefighters’

ability to contain fires, death and injury rates have plateaued over the last two decades (Okray & Lubnau, 2004). Veterans in the emergency service field have argued strongly for the implementation of CRM to fill the gaps in technical based safety training programs by including the human aspect of situations thereby potentially reducing these stagnant death and injury rates. Specifically, Lubnau and Okray (2001) argue;

The fire service now finds these proven concepts knocking at its door. Equipment is becoming more and more reliable. Firefighting techniques and strategies are becoming scientifically honed, and new technologies for firefighter safety are being brought to the market daily. At the same time, firefighter fatalities and injuries on the emergency scene have plateaued. . . . The time has come for these aviation principles to be adopted by the fire service. However, for that to happen, a whole new mind set and organizational culture will need to be instilled from the top down. Modifying an organization's leadership style from military and authoritarian to team leadership takes extensive training and a courageous release of control by those in command. The time for the application of the old saying "Only the lead dog has a good view" to the fire service has come and gone. The fire service needs to take on a new and tried approach that takes advantage of the entire team's skills and senses, not just those of the leader. Leaders must buy into the concepts of CRM completely if these principles are to be successfully adopted (p. 8).

From existing CRM models, training programs for the fire and emergency services (often referred to as Team Resource Management – TRM) have been adapted to focus on basic skills and attitudes including communications, situational awareness, problem solving, decision making, and teamwork (Hagemann, Kluge & Greve, 2012). The goal of CRM/TRM programs is to enable emergency service teams to make the right decisions in the field quickly, safely, and collegially. As such, its principles stress the necessity of both having strong leadership in place to guide a crew's decision-making process, while encouraging individual team members to share critical information to support the team leader in making the crucial decisions during an emergency. Specifically, the CRM/TRM process works to break down common communication barriers by focusing on the team as a whole with a common goal using the following six steps: 1) Using inquiry to evaluate procedure; 2) Using advocacy to respectfully question authority; 3) Using conflict resolution techniques to learn from errors; 4) Using strong leadership to make group decisions; 5) Observing and critiquing team decisions to meet mission goals; and 6) Fostering an open and accepting team environment, where members discuss options for team improvement (LeSage, Dyar, & Evans, 2011).

CRM/TRM Program Evaluation

Evaluation of the effectiveness of prevention based training programs is, by nature, inherently difficult, as measuring what one has prevented is not generally feasible beyond ‘what if’ conjecture. However, its merit in the aviation industry is virtually unquestioned, to the extent that it has become standard mandatory aspect of safety training at all levels. Empirically speaking, throughout its deployment across the diverse fields, various studies have found positive results using the criteria of reactions, attitudes, knowledge acquisition, and behaviors (Fisher, et al., 2000; Helmreich & Foushee, 1993; Helmreich & Wilhelm, 1991; O’Connor, et al., 2008; Salas, Prince, Bowers, Stout, Oser, & Cannon-Bowers, 1999a; Salas et al., 2006). Furthermore, it is generally assumed that positive changes in knowledge – i.e., cognitive level - and attitudes – i.e., affective levels - are important precursors for changes in safety-relevant behavior (O’Connor et al., 2003).

Salas, Burke, Bowers, and Wilson (2001) and Salas et al. (2006) reviewed numerous studies, which demonstrated that CRM/TRM training had a positive impact on the team members’ reactions and their subjectively rated learning success as well as on their declarative knowledge acquisition (O’Connor, Flin, Fletcher, & Hemsley, 2003; Salas, Fowlkes, Stout, Milanovich, & Prince, 1999). Additionally, the CRM/TRM training was shown to have a positive impact on teamwork-relevant attitudes (Gregorich, Helmreich, & Wilhelm, 1990; Helmreich and Wilhelm, 1991). As the implementation of CRM/TRM programs gain wider acceptance throughout the Emergency Services field, more empirical studies will be necessary to help tailor program outcomes and delivery modes for specific contexts as well as to provide an overall evaluation of its relative applicability and effectiveness.

Conclusions

CRM has a strong and solid history as a method for the effective management of teams and can have particular application in areas where optimal team functioning is necessary in high stress situations. Based upon its continuing success, new fields continually embrace its core concepts and modify its application to their specific contexts. In the fire and emergency services fields, CRM/TRM continues to gain support as a means of implementing a new philosophy of participative management to replace the traditional idea that “Only the lead dog has a good view” (Lubnau & Okray, 2001, p. 8). As evidence of this, In March of 2015 The Regional Alliance for Firefighting Training will host the First Annual Crew Resource Management National Symposium based on fostering awareness and application of CRM and “a commitment to change fire and emergency service leadership and operating cultures that have evolved over generations of time” (Regional Alliance, 2015, para. 1).

If current trends were to continue, over the next decade approximately 1000 fire fighters would die and a million would be injured. Combined with comprehensive technical training and skill building programs CRM can enhance a team’s ability to respond in a coordinated and cooperative manner that utilizes the strengths of each member. In emergency services contexts this can equate to saving lives.

Methods

Study Selection

An argument presented in this paper is that there are few Crew Resource Management (CRM)/Incident Command System studies in the fire service with quantified results. An electronic search was conducted using ProQuest database, and general internet searches for previous studies. Because of the transition of the U.S. fire service to a broader emergency services scope, the search was widened to incorporate emergency medical services as well as fire studies. Three studies (four sets of results) were identified for inclusion in the statistical meta-analysis comparison. These studies all included some form of testing to determine improvement in CRM concepts after training was provided and presented quantitative statistical results using appropriate statistical analysis.

Glow, Colucci, Douglas, Allington, Curtis, & Hall studied medical preparedness in rural settings. Their study involved hospital and pre-hospital Fire and Emergency Medical Technicians (EMT) pre-hospital staff in the areas of communication, incident command systems and triage (2013). A group of 175 were offered a one day training session which included two exercises and four one hour blocks of didactic instruction. The pre and posttests had 18 questions. The authors noted that fire personnel exhibited higher baseline test scores than any other group, but that all groups showed improvement after the training. Glow et al. compared their data using a one way analysis of variance due to multiple professional groups in the study. The authors noted that “the participants volunteered for training so selection bias could not be ruled out” (p. 340). Another weakness noted was the design which had no control group. The results of 70 firefighter and EMS personnel were used for the Meta-analysis.

Fisher, Phillips & Mather (2000) conducted a study to determine if CRM could play a positive role in reducing medical accidents. The study focused on civilian medical aircrew and was a posttest only control group design. Subjects were randomly selected for a survey. Based on their responses, they were placed in the control (not trained) or treatment (CRM trained – all three sessions) group. The survey had 15 questions specifically assessing CRM concepts and was patterned after a survey used by the NASA Ames Research Center. Responses from 144 surveys were evaluated. Eight people had not received training, 58 air crew had received all three modules of CRM training. The remaining surveys were not used in their comparison. Scores for the control and treatment groups were evaluated using a *t*-test for independent samples yielding positive results ($p=.031$). All subject scores were used in the meta-analysis.

Hagemann, Kluge and Greve (2012) studied the effects of CRM training in the fire service. This German study compared three different groups of scores; a pretest, posttest one day after training and a posttest 7 months after CRM training. The training was one-half day. CRM knowledge was significantly higher at one day and 7 months post training than prior to training. The authors noted however, that there was a significant decrease in CRM knowledge 7 months post training. Data were reported as paired *t*-test results between the pre-test score and either the one day or 7 month post training score. Findings showed significant improvement to CRM knowledge to the $p < .001$ for 1 day ($n=28$) post training and $p=.001$ for 7 months ($n=11$) post training. The data for overall knowledge (compilation of 5 different elements of CRM to include shared mental models, communication, situational awareness, team competencies and feedback) were used in the meta-analysis.

The researchers excluded studies that did not have some form of assessment test for CRM improvement. Several studies indicated that CRM had been implemented with no results reported on trainees' grasp of CRM concepts. Additionally, CRM studies in other high risk occupations

were excluded (such as oil rigs) because it was determined that the job settings were too different than what would be experienced in the fire and EMS settings.

Possible publication bias could exist with these results since those who implement training programs would be more likely to report and publish outcomes that were successful. It is important to acknowledge this potential bias and use conservative measures when reporting meta-analysis results (Gay, Mills, & Airasian, 2006).

Treatment of the Data

Four sets of study results in the fire and emergency services were analyzed using meta-analysis statistical tools. A continuous measure statistic (difference of means divided by the pooled standard deviation) was used to calculate the standardized mean difference (effect size). In this study, the Hedges g formula was used to express the standardized mean difference with a correction for small sample sizes (DerSimonian and Laird, 1996; MedCalc, 2014b).

The researchers used MedCalc version 14 software to calculate p values for both the fixed and random effects models. The studies evaluated were statistically weighted based primarily on their sample sizes (MedCalc, 2014b). The random effects model assumes that the true effects vary between studies and generally gives a more conservative estimate of the common effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009). The researchers would suggest that the random effects model is the most effective way to evaluate these data due to the different teaching and testing methods used in the studies.

Heterogeneity measures how much variation, not due to random chance, between groups of studies. Cochran's Q and the I^2 statistic were used to evaluate the possible heterogeneity between the studies. Regarding interpretation of the Q statistic, Higgins, Thompson, Deeks, & Altman (2003) suggested a value of 0.10 as a cutoff for significance. A Q result lower than 0.10 would indicate significant heterogeneity. Higgins et al. also suggest that the I^2 statistic is a good indicator of the percentage of variation between studies. The higher the percentage, the more variation or heterogeneity between studies. I^2 has a scale from 0% to 100% offering simple interpretation as well as comparability between the results of two or more meta-analysis studies.

Results

Table 1 shows a summary of the studies included in the meta-analysis. The aggregate number of test results examined was 283. Three of the four sets of results used a one-group pretest-posttest design. All of the studies included assessment testing on CRM concepts showing statistically significant positive results. A summary of study design, sample sizes, intervention and outcomes follows.

Table 1.

Summary of Studies Included in the Meta-analysis

Study	Design	Sample test results	Intervention	Outcomes

Glow, Colucci, Allington et al. (2013) Fire fighters /prehospital EMS	One-group pretest-posttest design. Scores of CRM trained (n=68) vs scores prior to training (n=70).	138	Crew Resource Management training course	p<.001
Fisher (2000) Aeromedical Aircrew	Posttest only control group design. Scores of CRM trained (n=59) vs those who were not trained (n=8)	67	Crew Resource Management Training course	p =.031
Hagemann, Kluge, Greve (2012) Fire fighters (1 day after training)	One group pretest-posttest design. Group tested before CRM training and one month after training.	56	CRM ½ day training session	p<.001
Hagemann, Kluge, Greve (2012) Fire fighters (7 months after training)	One group pretest-posttest design. Pre training and 7 month post training scores compared	22	CRM ½ day training session	p=.001

Note. Table adapted from the following: Does crew resource management training work? Fisher, J., Phillips, E., & Mather, J. (2000). Managing multiple-casualty incidents: A rural medical preparedness training assessment. Glow, S., Colucci, V., Allington, D., Noonan, C., & Hall, E. (2013). Measuring the effects of team resource management training for the fire service. Hagemann, V., Kluge, A., & Greve, J. (2012).

Data were analyzed using MedCalc version 14 software (2014b). The confidence intervals are all positive meaning that the studies showed significant results. The total fixed and random effects models showed a significance level of p<.001. The fixed model showed a Standardized Mean Difference of 1.62. The Random Effects model was 1.726. Details are shown in Table 2.

Table 2

Meta-Analysis Results

Study	Total	SMD	95% CI	t	p
Glow et al., (2013) EMS and Firefighters	138	1.445	1.068 to 1.821		
Fisher et al., (2000) Aeromedical Aircrew	67	1.139	0.370 to 1.909		
1 day Hagemann et al., (2012) Firefighters	56	2.918	2.153 to 3.683		
7 mo Hagemann, et al., (2012) Firefighters	22	1.435	0.468 to 2.402		
Total (fixed effects)	283	1.620	1.329 to 1.910	10.969	<0.001
Total (random effects)	283	1.726	1.000 to 2.452	4.678	<0.001

Note. Data calculated using MedCalc version 14 software, Meta-Analysis Continuous Test. Standardized Mean Difference (effect size) was calculated using the Hedges g statistic. Standardized mean differences greater than .8 indicate a large effect size (MedCalc, 2014a).

The results indicate that there is significant agreement between these studies regarding improvement in CRM concepts based on the standard mean differences. All exhibited large effect sizes. The fixed and random effects models also showed similar large standard mean differences. The forest plot showing the 95% confidence intervals of the standardized mean differences, fixed effects and random effects models is shown in Figure 1.

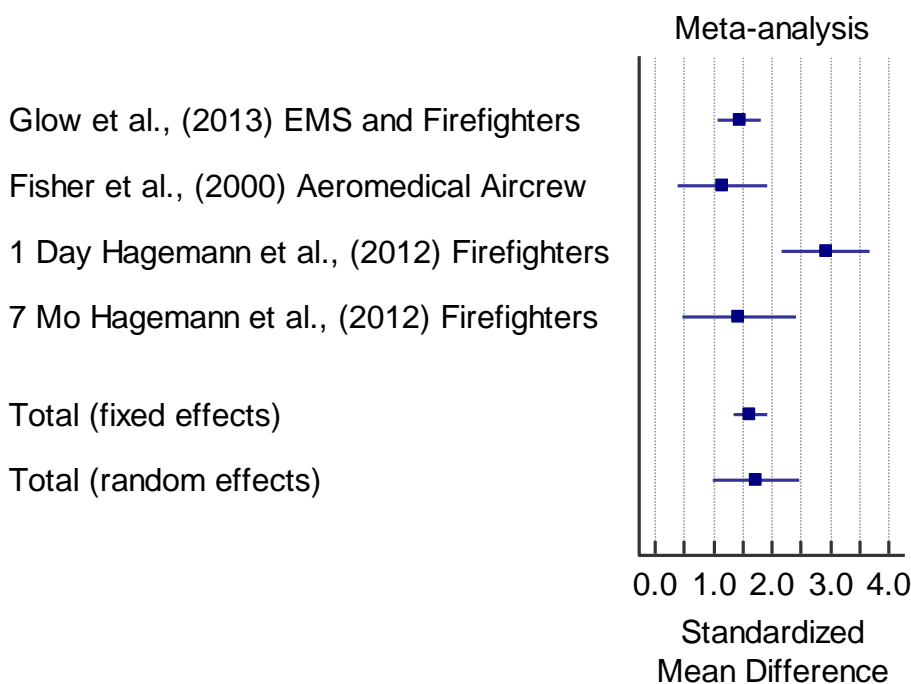


Figure 1. Forest plot showing 95% confidence intervals of standardized mean differences (MedCalc, 2014b).

Test of Heterogeneity

The data were also analyzed for heterogeneity. The evaluation yielded a significant Q value of 14.143 (3 degrees of freedom, $p=.0027$). The I^2 statistic indicated a 78.79% inconsistency level that is not due to random chance. The 95% confidence interval for I^2 was 43.14 to 92.09, (Medcalc, 2014). There was a high level of variation in these results probably based on different intensity of training sessions and different testing methods to assess student acquisition of CRM concepts.

Conclusions

The data indicate that the standardized mean differences of the four sets of study results show a statistically significant positive effect of the CRM training ($p<.001$). These results support the argument for CRM training in the fire service. Additionally, there was a significant amount of heterogeneity between the studies as the I^2 statistic indicated that 78.79% of the variation was not due to random chance. The high level of heterogeneity is not surprising due to the different training courses and testing methods used in the studies compared in the meta-analysis.

One difference noted in the Hagemann et al. study was the decline of CRM knowledge between 1 day after training and 7 months after training. Student scores dropped 13 points ($p < .001$). This result supports the need for continuous training. “The implication is that recurrent TRM (CRM) training is also needed, for example, in fire service teams and has to be developed and applied in practice” (Hagemann et al., 2012, p. 2446).

The difficulty in any meta-analysis is to identify studies with similar methodologies that report results using quantitative data. Some studies were excluded because they did not test for CRM concept retention by students. Additionally, possible publication bias may exist since authors are more likely to publish if they can show positive results of training programs. It can also be argued that any tool such as CRM that enhances decision-making and reduces mistakes merits consideration. The results of this meta-analysis support the idea of CRM in the fire service.

Recommendations for Further Research

Four recommendations come directly from authors of the studies in the meta-analysis

1. Interdisciplinary training consisting of interdisciplinary didactic and functional exercise training can result in improved competence of emergency services personnel. This training should be conducted periodically (Glow et al., 2013).
2. Ongoing training should be tailored to specific professional disciplines (Glow et al., 2013).
3. CRM training has shown to be effective. Leadership needs to create a continuing culture of CRM principles (Fisher et al, 2000).
4. There is a need not only for initial CRM training, but recurrent CRM training as well (Hagemann et al., 2012).

Future studies should not just focus on if CRM training was implemented in a fire station, but focus on the outcome of the training through testing. Future researchers should continue to evaluate the effectiveness of initial and recurring CRM training.

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