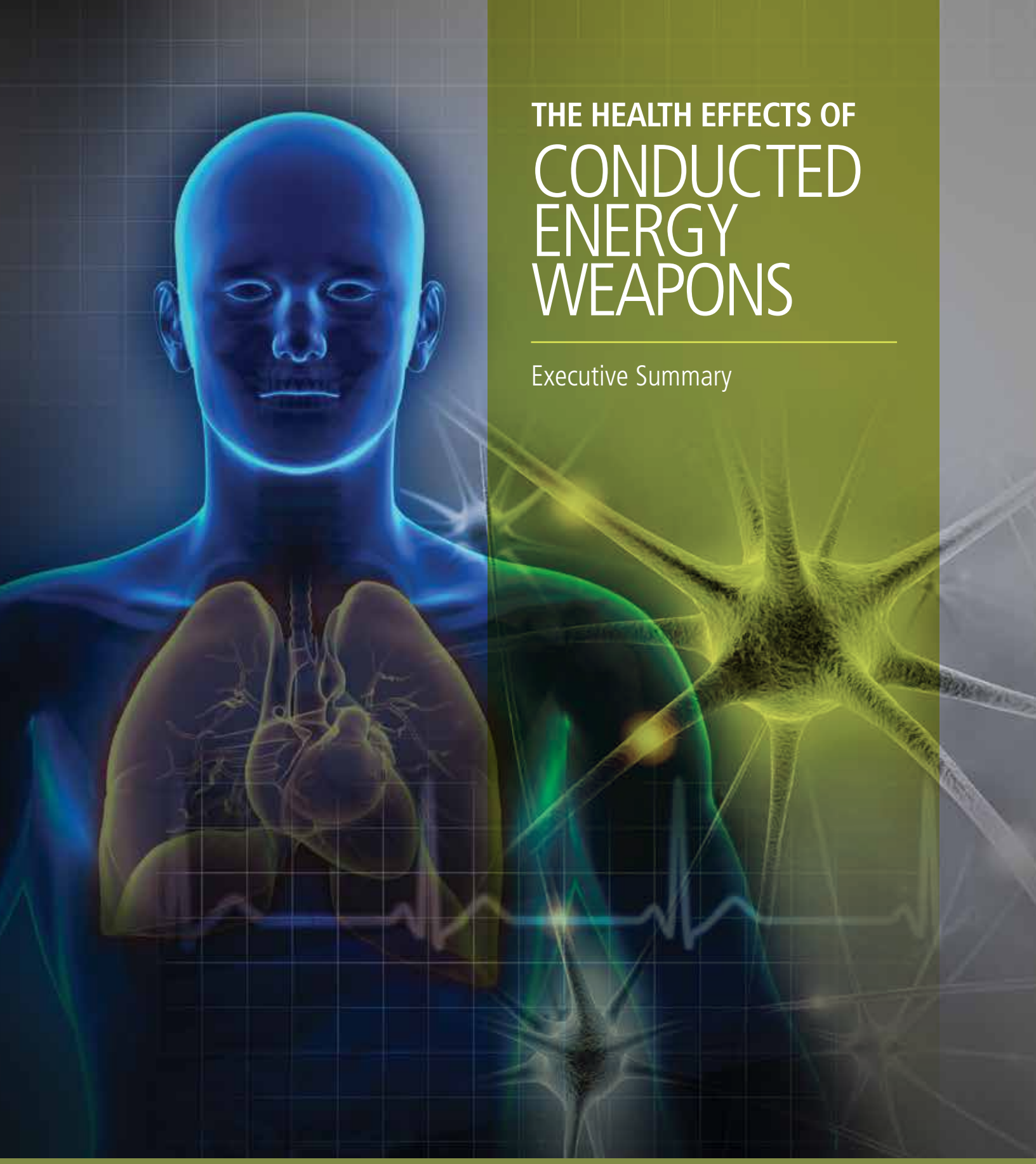

THE HEALTH EFFECTS OF CONDUCTED ENERGY WEAPONS

Executive Summary

Council of Canadian Academies
Conseil des académies canadiennes

Canadian Academy of Health Sciences
Académie canadienne des sciences de la santé

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Executive Summary

THE COUNCIL OF CANADIAN ACADEMIES & THE CANADIAN ACADEMY OF HEALTH SCIENCES
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Letter from the Chair

Although relatively new to modern policing, conducted energy weapons (CEWs) have become widespread tools used by law enforcement and public safety personnel in all jurisdictions across Canada. Because of this widespread use and current scrutiny in both scientific and public spheres, all Canadians have a vested interest in determining what is known and not known about the physiological and health effects associated with CEW use.

The Expert Panel on the Medical and Physiological Impacts of Conducted Energy Weapons is deeply appreciative of the opportunity to explore this important question and for the input and assistance it received throughout the course of its work.

Several individuals and organizations provided very helpful advice and assistance early in the process. In particular, Len Goodman, Head (acting), Individual Behaviour and Performance Section, Defence Research and Development Canada-Toronto, and Donna Wood, Project Manager, Conducted Energy Weapons Strategic Initiative (CEWSI), Defence Research and Development Canada-Centre for Security Science, provided excellent background on the work of the CEWSI more broadly and guidance related to the scoping of the assessment questions. Sergeants Steven De Ville and Greg Borger of the Ottawa Police Service in Ontario also generously provided their time and experience to guide the Panel through a hands-on demonstration of CEW devices and their uses in policing use-of-force models.

The Panel also wishes to acknowledge the staff of the Quality Engineering Test Establishment research facilities of National Defence and the Canadian Forces, who were very helpful in providing a tour of their research testing facilities in the initial stages of the assessment and instrumental in providing testing data related to their work with CEWs for use in the report. The Panel also appreciates the reconnaissance work of Public Safety Canada and its important consultation activities into the use of CEWs in Canada.

Finally, the Panel is most grateful for the outstanding support it received from the staff members of the Council of Canadian Academies, whose names are listed below.

The Honourable Justice Stephen T. Goudge
Chair, Expert Panel on the Medical and Physiological Impacts of Conducted Energy Weapons

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Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Council of Canadian Academies and the Canadian Academy of Health Sciences (CAHS) for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations.

The reviewers assessed the objectivity and quality of the report. Their submissions — which remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions nor did they see the final draft of the report before its release.

Responsibility for the final content of this report rests entirely with the Expert Panel on the Medical and Physiological Impacts of Conducted Energy Weapons, the Council, and CAHS.

The Council and CAHS wish to thank the following individuals for their review of this report:

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The report review procedure was monitored on behalf of the Boards of the Council and CAHS and the Joint Scientific Advisory Committee by **Dr. Jean Gray, C.M., FCAHS,** Professor of Medicine (Emeritus), Dalhousie University. The role of the Report Review Monitor is to ensure that the Panel gives full and fair consideration to the submissions of the report reviewers. The Boards of the Council and CAHS authorize public release of an expert panel report only after the Report Review Monitor confirms that the report review requirements have been satisfied. The Council and CAHS thank Dr. Jean Gray for her diligent contribution as Report Review Monitor.

Elizabeth Dowdeswell, O.C., President and CEO
Council of Canadian Academies

Tom Marrie, FCAHS, President
Canadian Academy of Health Sciences

Executive Summary

Conducted energy weapons (CEWs) are devices that use electrical energy to induce pain or to immobilize or incapacitate a person. The broad use-of-force continuum used by law enforcement and public safety personnel ranges from the physical presence of an officer through to use of deadly force. CEWs are one of several options on this continuum. They are typically used to facilitate arrests of uncooperative individuals who are resisting. The induced loss of voluntary muscle control causes subjects to fall to the ground, where they may be subdued and taken into custody. Subjects are not meant to experience any lasting effects after application of the device.

CEWs are used by law enforcement agencies around the world. They were first adopted by some Canadian law enforcement agencies in the late 1990s. Currently, there are approximately 9,174 CEWs in use in Canada and although the number varies based on jurisdiction, all federal, provincial, and territorial jurisdictions use the device in some capacity. Decision-making about the protocols for selecting, acquiring, and using CEWs is undertaken by local agencies and varies across geographies. The decision to deploy a CEW resides not only at the institutional and management levels, but also in the field and in the moment. In any policing scenario, the officer on the scene decides whether and how to use force by following protocol, weighing options and outcomes, and estimating risk within the limitations of information available in real time.

CEWs are intended to be safe and potentially injury-reducing compared to alternative interventions, but they are not necessarily risk free. Scientific research and public forums have discussed and debated the potential risk, harm, and appropriateness of CEWs as a use-of-force option. Based on media reports and documented inquest processes alone, to date at least 33 deaths have been proximal to CEW use in Canada, but were not necessarily results of CEW deployment. There is no synthesized body of evidence documenting the number of deaths related to all other use-of-force encounters to confirm or compare with this number. Given current scrutiny, a scientific consensus on what is known and not known about the physiological and health effects associated with CEW use is essential.

In 2010, the Centre for Security Science at Defence Research and Development Canada (DRDC) began undertaking the Conducted Energy Weapons Strategic Initiative (CEWSI), in partnership with the Director General for Policing Policy at Public Safety Canada. One of the CEWSI objectives was to convene a panel of medical experts to conduct an independent evaluation of existing research aimed at examining the medical and physiological impacts of CEWs. To fulfill this objective, DRDC (the Sponsor) asked the Canadian Academy of Health Sciences (CAHS) to conduct an independent, evidence-based assessment of the state of knowledge in this area. CAHS established a partnership with the Council of Canadian Academies (the Council). Working collaboratively with CAHS, the Council acted as the secretariat for the science-based exploration of the evidence.

The Council and CAHS were asked to answer the following three main questions:

1. What is the current state of scientific knowledge about the medical and physiological impacts of conducted energy weapons?
2. What gaps exist in the current knowledge about these impacts?
3. What research is required to close these gaps?

To address the charge, the Council and CAHS assembled a 14-member multidisciplinary panel of experts from Canada and abroad (the Panel). This report is based on the consensus reached by Panel members through their review and deliberation of the evidence: major evidence syntheses, reviews, and books; peer-reviewed primary research; other relevant literature on broad topics such as research ethics, electrophysiology, and electrical engineering; technical documents outlining testing results established by DRDC; and a hands-on demonstration of CEW deployment during a site visit to the Quality Engineering Test Establishment (QETE) research facilities of the Department of National Defence Canada and the Canadian Forces.

THE FINDINGS

The Panel identified five key findings that serve to answer the charge put forward by DRDC. The following is a description of those findings; a more detailed discussion is contained in the Panel's full report.

1. **CEWs are based on the principle that the electrical discharges delivered by the device are powerful enough to effectively stimulate motor and sensory nerves, causing incapacitation and pain, but too brief to directly stimulate other electrically excitable tissues. Because the electrical characteristics of CEW devices are variable and evolving, each CEW device must be tested on its own merit to assess performance as well as the ability to induce incapacitation and potential adverse health effects.**

CEWs deliver short, repeated pulses of electricity to the skin and subcutaneous tissues through two metal probes. They can be used in two operating modes: probe mode and drive stun mode. In probe mode, a pair of metal darts deploys from the CEW, spreads apart, and penetrates and attaches to the subject's clothing, skin, and soft tissues. The darts are connected to thin electrical wires that conduct the electrical discharge from the device. If the two darts are spaced widely enough across the body, the resulting effect is incapacitation. In drive stun mode, the device is pressed directly against the subject, causing localized pain. Probe mode is more likely to result in current flow through the tissues in the chest — including, potentially, the heart — and carries the most risk of unwanted cardiac or other health effects.

In addition to causing pain, CEWs influence the peripheral nervous system in a way that causes temporary, involuntary, and uncoordinated skeletal muscle contractions. Along with factors specific to the individual and context, the response of the human body to a CEW depends on the strength, duration, and waveform of the electrical discharge, as well as on the timing of the applied electrical current in relation to the natural electrical activity occurring in the body. The ability of CEWs to stimulate some tissues (e.g., nerve cells) and not others (e.g., heart cells) is dependent on these characteristics. Nerve cells have waveforms that are much shorter than those produced by the heart muscle. The duration of electrical stimulation required to exceed the threshold in a cardiac muscle cell is about 10 to 100 times longer than in a motor or sensory nerve cell. Therefore, the principle guiding the functioning of CEWs is that the short-duration electrical discharges it delivers are highly effective in stimulating nerves, causing incapacitation and pain, but are much less effective in stimulating the heart muscle and thereby inducing potentially fatal disruptions to the heart's rhythm and pumping ability. Specifications between CEW devices are variable, however, and may change with use and under different conditions. CEW devices and the variations between them are also constantly evolving, so knowledge based on any particular model does not necessarily translate to other devices, and the characteristics of newer devices are unknown. Evaluating the intended and unintended effects of a CEW requires testing each device on its own merit and understanding the context and conditions under which it is used.

2. **Certain physical injuries such as superficial puncture wounds are common as a result of CEW discharge, but rarely pose serious medical risks. Although it is difficult to state any firm conclusions on the neuroendocrine, respiratory, and cardiac effects of CEWs due to an absence of high-quality evidence, available studies suggest that while fatal complications are biologically plausible, they would be extremely rare.**

The Panel identified a range of CEW-induced physical injuries. Superficial physical injuries resulting from CEW probes are common, while more severe injuries resulting from CEW probes, muscle contractions, and falls associated with incapacitation occur much less frequently. The Panel concentrated on acute, short-term physiological and health effects resulting from the electrical current of CEW devices and having the most potential for sudden unexpected death. Because sudden unexpected death is likely the end result of a variety of intersecting factors that involve the neuroendocrine, respiratory, and cardiovascular systems, the Panel focused on physiological changes in these systems, including activation of the human stress response and build-up of related levels of stress hormones such as catecholamines; mechanical impairment of breathing, changes in blood chemistry, and resulting acidosis; and changes to heart rhythm and rate and the potential for arrhythmias. The Panel also examined a range of co-factors that individually, or in combination, could increase the risk or severity of these effects and increase the risk of sudden unexpected death. From the Panel's review of the available literature, the majority of which focus on cardiac effects, several findings emerged:

- Although limited studies suggest CEW exposure can induce the stress response and increase hormone levels, these increases are of uncertain clinical relevance. It is also unclear to what extent the discharge of a CEW adds to the high level of stress already being experienced by an individual in an arrest scenario.

- Studies of animals subjected to prolonged or repeated CEW exposure indicate the potential for respiratory complications (e.g., pronounced acidosis). Although published experimental data identify respiratory changes in healthy human subjects typical of vigorous physical exertion, studies involving more heterogeneous groups or humans subjected to prolonged or repeated exposure have not been conducted.
- Some animal studies suggest CEWs can induce fatal cardiac arrhythmias (abnormal heart rhythm) when a number of discharge characteristics, either alone or in combination, are in place: probe placement on opposite sides of the heart (i.e., current is delivered across the heart), probes embedded deeply near the heart, increased charge, prolonged discharges, or repeated discharges. These studies indicate the biological plausibility of adverse health outcomes following CEW exposure.
- A small number of human cases have found a temporal relationship between CEWs and fatal cardiac arrhythmias, but available evidence does not allow for confirmation or exclusion of a causal link. If a causal link does exist, the likelihood of a fatal cardiac arrhythmia occurring would be low, but further evidence is required to confirm the presence and magnitude of any risk.
- The roles of co-factors common to real-world CEW incidents (e.g., intoxication, exertion, restraint) and other co-factors (e.g., body type, existing health complications) that may increase susceptibility to adverse effects have not been adequately tested to properly establish an understanding of increased vulnerability in humans.

These conclusions are limited by a number of challenges presented by the available laboratory-based experimental research studies, including translation of findings from computer and animal model studies to humans, human studies with mainly healthy subjects who do not represent the varying populations involved in CEW events, the absence of adequate control groups, lack of diverse and robust experimental designs and monitoring, and small sample sizes. Large-scale population-based studies that better capture the complexity of real-world CEW deployment scenarios, along with a range of potential co-factors, are lacking.

3. **Sudden in-custody death resulting from a use-of-force event typically involves a complicated scenario that includes multiple factors, all of which can potentially contribute to a sudden unexpected death. This makes it difficult to isolate the contribution of any single factor. Although the electrical characteristics of CEWs can potentially contribute to sudden in-custody death, given the limited evidence, CEW exposure cannot be confirmed or excluded as the primary cause of a fatality in most real-world settings.**

Sudden in-custody death refers to rapid, unexpected death during detention of individuals by law enforcement or public safety personnel. These fatalities typically occur during a complicated scenario, which may include agitation, physical or chemical restraint, disorientation, stress or exertion, pre-existing health conditions, and the use of drugs or alcohol, all of which can potentially contribute to the death. This makes it difficult to isolate the contribution of any single factor. Although evidence shows the electrical characteristics of CEWs can potentially contribute to sudden in-custody death, no evidence of a clear causal relationship has been demonstrated by large-scale prospective studies. In a few coroner reports, however, CEWs were ruled as the primary cause of death in the absence of other factors when excessive exposure was present. Conversely, it has been argued that CEWs could potentially play protective roles in terminating situations that might otherwise culminate in sudden in-custody death. Given the limitations and scarcity of the evidence, a clear causal relationship between CEW use and sudden in-custody death cannot be confirmed or excluded at this time. In addition, there is insufficient evidence to determine whether the use of CEWs increases or decreases the probability of sudden in-custody death in the presence of co-factors such as mental illness or excited delirium syndrome (a highly controversial classification denoting a state characterized by signs and symptoms such as agitation, elevated body temperature, disorientation, and aggression). If a causal relationship does exist, the likelihood that a CEW will be the sole cause of a sudden in-custody death is low. The extent to which the device would play a role in any death is unclear and dependent on the co-factors involved. Further research is needed to better define these relationships.

4. **There are a number of overarching challenges in funding, conducting, and interpreting CEW research, which create knowledge gaps related to the health effects of CEWs across varying populations and across the operational settings in which CEWs are deployed.**

CEWs have been studied in the laboratory, with computer or animal models and human subjects, and in the field, with real-world incidents. Animal models allow for more intensive experimental interventions, which can clarify the various parameters required to predictably achieve physiological and health effects following CEW exposure. Despite the potential advantages of these studies, their applicability and generalizability to real-world CEW exposures is unclear. The Panel concluded that prospective large-scale population-based field studies involving detailed and consistent collection of information on the characteristics of the subjects and the events surrounding CEW incidents are essential for improving the quality of evidence. However, low injury rates and lack of standardization, among other challenges, make it difficult to establish meaningful associations. Because of the challenges present in the current evidence, the Panel concluded that key issues have not been fully explored across varying populations or in the operational settings in which CEWs are actually deployed, thus pointing to several priorities for future research:

- To what extent can the electrical characteristics of CEWs cause cardiac arrhythmia and sudden in-custody death in humans when deployed in real-world operational settings?
- Are certain groups or individuals with particular conditions at increased risk for adverse outcomes related to CEWs, and if so, what are the key co-factors?
- What CEW design and deployment features could minimize the risk of adverse health effects?

The Panel further identified five overarching gaps in health-related CEW knowledge:

Establishment of causal relationships – Establishing causality is not a simple task. While some research indicates an association between CEW exposure and certain health effects, other research does not, and in many cases there is simply not enough research to make any definitive conclusions. The effects of confounding factors may provide a number of possible explanations for those relationships, or the lack thereof. Thus, the Panel considered it difficult to establish the extent to which CEW exposure could act as the primary cause of severe adverse health effects in real-world settings, largely due to the challenge of weighting the contribution of multiple factors.

Establishment of time necessary for probability – There are no guidelines to specify the length of time needed between CEW discharge and the development of a health effect that would allow one to conclude the CEW was responsible for that effect. It may be beneficial to consider a continuum where, as the time of a health effect moves farther away from the time of deployment, the probability that a CEW was directly responsible for that event diminishes.

Understanding of varying populations – Laboratory-based experimental CEW research on human subjects typically involves healthy, physically fit volunteers. There is therefore a paucity of knowledge of the health effects associated with CEW use outside controlled settings and within varying, potentially vulnerable populations. Large-scale population-based field studies involving detailed and consistent collection of information on the characteristics of the subjects and the events surrounding CEW use hold promise for addressing ethical constraints and identifying health effects across a range of populations.

Lack of standardization – The ability to carry out adequate surveillance and population-based study is hindered by lack of standardization and inconsistent reporting and record-keeping practices related to use-of-force events. There are few central registries with standardized recording of CEW incidents by both law enforcement and medical personnel. The lack of standardization hinders the ability to conduct population-based studies and to form evidence-based conclusions about the relationship between CEW use and adverse health effects.

Transparency and independence of research – Many research studies of CEWs appear to be affiliated with, or receive support from, CEW manufacturers or individuals with perceived conflicts of interest (e.g., paid medical experts), and funding sources are not always transparent. Although these studies may be scientifically robust, there is a perceived conflict of interest that limits their widespread acceptance. Independent research by organizations without financial or other ties to CEW manufacturers or others with perceived conflicts is desirable.

5. **Filling gaps in the state of evidence on the physiological and health effects of CEWs can best be achieved through a series of integrated strategies that focus on better surveillance, monitoring, reporting, and population-based epidemiological studies.**

The Panel was challenged with identifying research activities and mechanisms that might address the knowledge gaps related to the physiological and health effects of CEW use. The Panel determined the need for a series of integrated strategies underpinned by surveillance, monitoring, reporting, and population-based epidemiological study. The following considerations could form the basis of this integrated response:

Standardizing and centralizing the recording of CEW incidents – Establishing common definitions of use-of-force and CEW use, and implementing a standard method of reporting to enable police and medical personnel to record a minimum level of information, would make it possible to compare various parameters at the population level. This process would be supported by the creation of a central repository for information about use-of-force in Canada.

Enabling comprehensive medical assessment following CEW exposure – When subjects are brought to hospitals following CEW incidents, health care professionals would benefit from guidance on relevant co-factors and specific physiological changes and injuries to assess for proper patient care. With this knowledge, health care professionals could more routinely perform medical examinations relevant for evaluating CEW effects. Innovative technologies could also be integrated into CEW devices to allow for the instant and automatic recording of health and circumstantial information.

Improving access to, and sharing and integration of, knowledge across fields – Researchers could benefit from improved access to law enforcement and medical records, based on what is ethically and reasonably possible. Respecting privacy concerns, a process could be established to anonymously share and link this information across disciplines, institutions, and jurisdictions. Improved access and linking of information could encourage investigation of a range of relevant phenomena and increase the number of high-quality publications that examine various associations.

Supporting large-scale, multi-site, population-based studies – Our body of knowledge would benefit from robust multi-national, prospective population-based studies in which a broad range of health care professionals are trained in the nature and breadth of CEW injury and conduct consistent, comprehensive, and detailed medical examinations of individuals exposed to CEWs. To enable scientific analysis and reliable comparisons across events, research protocols would benefit from dynamic evidence-gathering methods allowing for the capturing of any unforeseen events (and their characteristics) that may arise during data collection.

Improving understanding of CEW risk relative to other use-of-force interventions – CEWs exist alongside (and can be used in conjunction with) many other possible interventions. To assess the risk of CEWs in relation to other interventions, future studies should consider comparing sudden in-custody deaths both related and unrelated to CEW incidents. Future studies would benefit from exploring the risks of not using a CEW in a given situation and accounting for jurisdiction and context, the use-of-force techniques and protocols in place, and the related adverse health effects that include morbidity, its severity, and mortality.

Understanding specifications of CEWs manufactured by a range of companies – By studying and comparing a broad range of devices, researchers could better understand how distinct outputs (e.g., waveform specifications and deployment modes) from CEWs are associated with physiological effects that vary in type and severity. Properly defining and articulating testing protocols for CEW devices would impose standard methods for assessing device performance over time. Enhancing knowledge in this area would help establish more robust information around safety parameters and technical specifications.

Furthering ethical, laboratory-based CEW research – Future computer modelling and animal studies would benefit from the application of novel approaches and larger sample sizes with proper comparison and control groups. Human studies would benefit from mimicking certain characteristics typical of subjects in the field (with appropriate ethical and safety constraints in mind), using more heterogeneous and larger study samples, and exploring extrapolation techniques.

CONCLUSION

The conclusions reached by the Panel are based on its interpretation of the best available evidence provided throughout the report. The Panel recognizes there are gaps in the literature and undoubtedly this poses challenges when assessing the physiological and health effects of these devices. Currently, there are numerous chances to rethink how we assess and communicate the health effects of CEWs and of use-of-force interventions more broadly. Opportunities exist for redesigning and improving research methodologies, standardizing the collection of information, and developing partnerships across disciplines, jurisdictions, and professional practices.

The Panel's report is intended to provide an in-depth and authoritative assessment of the state of knowledge regarding the relationship between CEW use and a range of health effects. In addition, the Panel acknowledges that there are a number of factors that go into decision-making related to CEWs that lie beyond the assessment of health effects; these factors must also be considered in any large-scale assessment of CEW use. This report must therefore complement other work on testing and approval procedures, motivations and protocols for appropriate use, safety and effectiveness standards, appropriateness of the devices compared to other use-of-force interventions, and other socio-political considerations that make up the broader package of information needed to make sound decisions about public health, policing, and CEW use in Canada.

This assessment presents an opportunity to inform municipal, provincial, territorial, federal, and international law enforcement practices, and provides a platform to encourage improved communication among these jurisdictions. Ultimately, public perception and emotion, although important considerations, should not lead the debate — a range of scientific inquiry, risk assessment, and evidence must guide policy surrounding the use of CEWs in Canada.