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Sports and the Environment: A Life Cycle Assessment of Children's Football and Hockey Equipment

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ABSTRACT Life-cycle assessment (LCA) is a technique that can be used to assess the environmental implications associated with all of the stages of a product's life, including raw material extraction, product creation, transportation, use, and disposal. This process can be used by designers to develop a more sustainable approach to their product or by consumers to become more informed on the environmental impacts of the product they are purchasing. Since the sporting goods industry and its products have significant environmental impact through energy use and emissions, this study aims to analyze the contribution of the life cycle stages of youth hockey and football equipment to the overall environmental load. In an effort to begin to assess the environmental impacts of sporting equipment, this study investigates material production, sports equipment creation, and use of hockey and football personal protective equipment (PPE). This analysis relates to the global concern of climate change since global warming potentials (GWP) will be assessed. We quantified the environmental burden of material production, sports equipment creation, and use through a TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) impact analysis, which reported impacts for global warming potential (GWP) as well as nine other environmental categories. Although previous LCAs have reported the use phase to be the most environmentally impactful stage in a textile's lifecycle, this was not the case for the LCA of children's football and hockey equipment, in large part because of the consumer behavior (not drying PPE).

INTRODUCTION

Life Cycle Assessment (LCA) is a methodological tool used to assess the environmental impact a product has throughout its entire life cycle. The results of the analysis can be used to describe the environmental, economic, and social effects attributed to the creation, distribution, use, and disposal of a specific good. Governments, companies, non-governmental organizations and citizens are becoming increasingly interested in the LCA of products in

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their efforts to improve the environmental impact of products and processes. Furthermore, it is important to note that LCA is a much more complex process than other techniques since it is a 'cradle to the grave' analysis which reviews the environmental effects of all aspects of the product under investigation (UNEP, 1996). It is concerned with the use of scarce resources as well as with the release of hazardous substances and ultimately focuses on either improving current production processes or comparing between impact of similar items.

The evaluation of a product through use of an LCA involves three stages. First, the goal and scope of the study is determined. Second, environmental impacts related to the energy and raw materials used are identified and quantified. Third, identified impacts are converted to common equivalence units in order to ensure consistency. For example, Global Warming Potential (GWP) is used within the Kyoto Protocol to the United Nations Framework Convention on Climate Change as a metric for weighting the climatic impact of emissions of different greenhouse gases (Shine *et al*., 2005).

Previous research has emphasized the importance of consumer use in the complete life cycle of a product. Sweatman and Gertsakis' research (1997) created a socio-environmental approach to product development that acknowledges the role that consumer behavior adds to a product's overall impact. Examples of life cycle assessments for sporting equipment has focused on the environmental impact of the materials composing the sports products. In the study performed by Subic *et al.* (2010), the researchers focused on the sporting goods industry's quest to embrace the sustainable design paradigm. They present findings on the LCA of composite tennis racquets, but do not address the environmental impact of its use by consumer. A tennis racquet does not require persistent washing and drying for re-use, so energy emissions caused by this are not included in the LCA. While not including the use phase is appropriate for a tennis racquet, that is not the case for sports equipment that requires ongoing care.

Existing LCA studies of textiles have generally focused on fabrics and their environmental implications, but little research has been done on the products like uniforms and other textile-based materials in the sporting goods industry. Recent research has even viewed the consumer as a stakeholder and has investigated consumers' disposal behavior as it pertains to fashion (Morgan *et al*., 2009) but this research is still lacking for sports uniforms and their associated special gear.

Furthermore, youth sports have not been addressed in previous LCAs on sports equipment. With the rise of core participation in children's sports, the environmental implications of youth sports must be addressed. Thus, this study aims to analyze the contribution of youth hockey and football equipment to the overall environmental load, specifically through measurement of GWP, an indicator for climate change. In an effort to begin to assess the environmental impact – defined by GWP – of sporting equipment, this study investigates material production, sports equipment creation, and use of hockey and football personal protective equipment (PPE) (see Figure 1).

This study, a novel application of an existing methodology, is unique to the field and will allow the sporting goods industry to prioritize improvements on their products. My research has three guiding hypotheses: (1) the use phase of the football and hockey PPE of interest will have the largest environmental impact measured by global warming potential (GWP), due to the continuous use by consumers and the energy required for washing and drying the gear for re-use, (2) that the creation phase of the sports equipment, including both padding and high-performance plastics, will have the second largest GWP due the level of greenhouse gas emissions in the manufacturing of the equipment and, (3) that hockey will have a greater GWP compared to football due to the larger amount of PPE required for play.

METHODS

Overview

In order to gather data on the materials and determine the masses of garments used in football and hockey PPE, I visited my local Dick's Sporting Goods. At the store, I massed each material found in the commonly worn football and hockey uniform and examined the attached tag to find component materials. For multi-material garments of which components were not listed on the attached tag, we purchased used equipment and deconstructed it to determine masses. Using these masses, I matched existing data in Eocinvent, GaBi Plastics, and GaBi Textile databases to the identified material. I then ran a TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) impact analysis using OpenLCA software (Figures 4 & 5). This study quantified the impact that inputs and cooresponding outputs of hockey and football PPE have on specific impact categories: ozone depletion, global warming potential, acidification, eutrophication, smog formation, human health impacts, and ecotoxicity (United States Environmental Protection Agency, 2016). The environmental impacts associated with hockey and football PPE were reported in common equivalence units, such as kilograms of carbon dioxide for global warming potential of all gases emitted during the various stages of the sports equipment's life cycle. The general life cycle of sports equipment to be considered in this study will consist of the production of component materials, equipment creation, transportation, and use (see Figure 1). We did not include the impacts of transportation in the LCA of football and hockey equipment because transportation impacts were assumed to be similar between both sports.

Production

When available, input information for a stage in production was taken directly from the Ecoinvent, GaBi Plastics, or GaBi Textile databases, which contain information on the environmental impacts of an assortment of materials. For a majority of the sports equipment considered in this study, component materials were listed on the attached tags. If percentages of component materials were listed, then the total mass of the equipment was multiplied by the corresponding percent to get the individual mass of each material. If percentages of component materials were not listed, we assumed an even split for each material (i.e. 50/50 for equipment consisting of two materials). When the attached tag did not list material make-up, the sports equipment was physically deconstructed and separated by material. All component materials were then massed, and existing data from EcoInvent, GaBi Plastics and GaBi Textile databases were matched to each material.

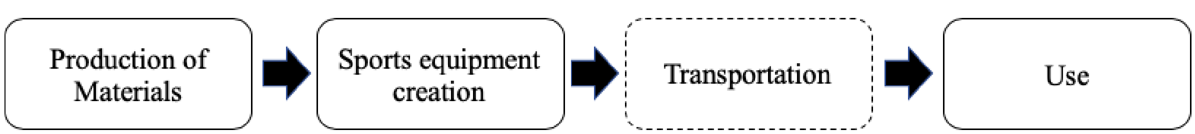

Figure 1. General life cycle diagram of sports equipment considered in this study.

Use

Use phase information was collected via SurveyMonkey with a personally created survey titled, “Sports and the Environment: Parent Athletic Survey” (see Appendix; Figure 6). The survey was distributed to groups of parents whose children play either hockey or football via social media and also to the St. Louis Rockets youth hockey team. The comboniation of Survey results consisted of 20 responses to four questions regarding the washing/drying of sports equipment. From the responses, we determined that hockey and football equipment was washed on average in a separate load once a month and air-dried. Use phase information was then taken from Beemkumar (2015), which provides time duration and energy consumption for various processes in the washing cycle at 2 kg of load. In order to compare the overall environmentl performance of hockey and footall PPE, a functional unit was defined. The functional unit for this study was determined as full body PPE used to comfortably shield the wearer’s body from injury during weekly sporting events for one year. From Beemkumar (2015), electricity use information for a 2 kg load was calculated for once a month washing and contributed to the use phase of hockey. For the use phase of football, electricity use information in watt-hour (Wh) was calculated for 1 kg of fabric, being that there are fewer items being washed per month (about half the mass of hockey equipment).

RESULTS

The TRACI impact category being analyzed in the LCA of football and hockey equipment is Global Warming Potential (GWP) measured in kg CO_2 eq. While the analysis reported ten TRACI impact categories, GWP was the primary indicator of environmental impact. Results for four of the ten reported TRACI impact categories are presented in the Appendix, Tables 1 and 2. “N/A,” which is listed under each evaluated impact category for both hockey and football footwear, signifies that environmental impact data was not collected for this element of PPE. Also found in the Appendix are Tables 3 and 4 which present the breakdowns of each full body hockey (Table 3) and football (Table 4) PPE items’ component materials and corresponding weights. These are listed in Tables 3 and 4 as well as the exact material taken from Ecoinvent, GaBi Plastics, or GaBi Textile databases which was then used to assess the environmental impact of youth hockey and football equipment via openLCA.Figures 2 and 3 show side-by-side comparisons of hockey and football full body PPE with their respective GWP in kg CO_2 equivalents (kg CO_2 eq.) (Figure 2) and each PPE items’ contribution as a percentage of the full body PPE for each sport’s GWP (Figure 3). For full body hockey PPE, the breakdown of individual items’ GWP impact was as follows: pants 16.0%, elbow pads 4.0%, shoulder pads 10.2%, shin guards 10.4%, gloves 6.3%, jersey 24.3%, stick 0.02%, socks 8.0%, puck 4.1%, and helmet 16.5%. Likewise, for full body football PPE breakdown of individual items’ impact was as follows: pants 23.0%, shoulder pads 36.6%, gloves 4.1%, jersey 5.8%, socks 3.4%, helmet 19.2%, and rubber football 7.9%.

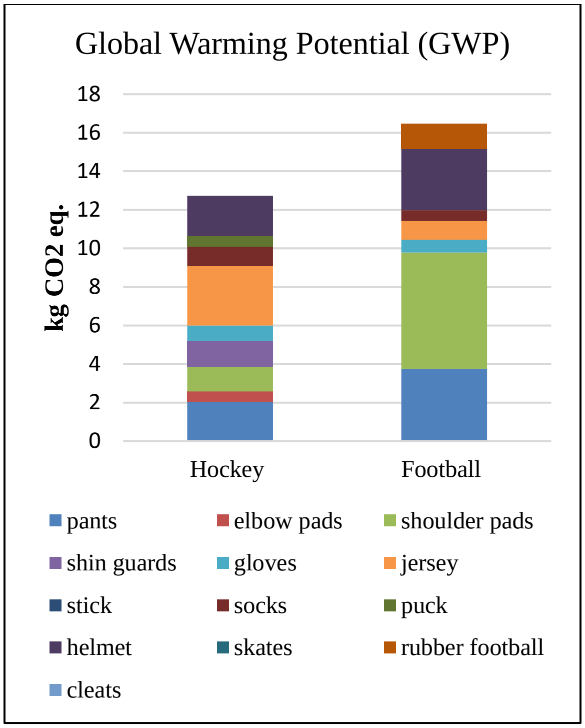

Figure 2. Global Warming Potential for full body Hockey and Football PPE (in kg CO_2 equivalents). For hockey equipment, the most emissions come from jersey (100% polyester) productions stages. In the case of football equipment, shoulder pads have the highest contribution to GWP.

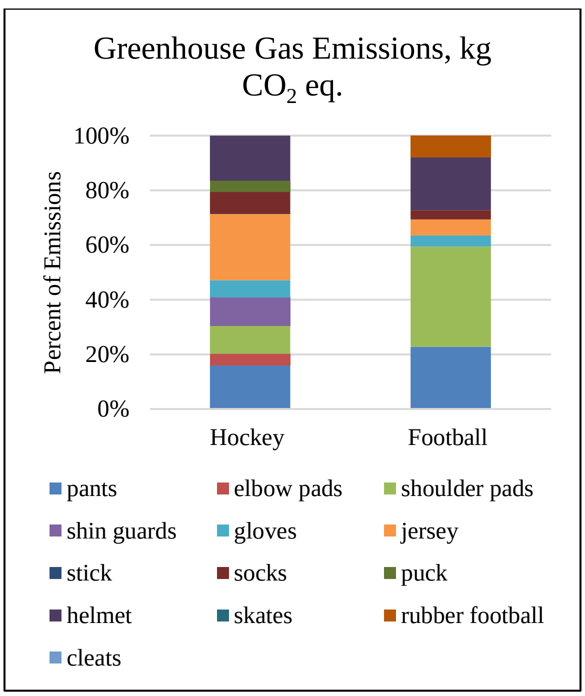

Figure 3. Greenhouse Gas Emissions for each element of Hockey and Football PPE as a percentage of each sport's total eminssions. For hockey equipment, the highest percent of emissions came from jersey (100%) polyester production stages. For the case of football equipment, shoulder pad production stages had the highest percent of gas emissions.

Additionally, Figures 4 and 5 show the same side-by-side comparisons of hockey and football full boy PPE Global Warming Potential in kg CO_2 equivalents but also include the use phase. For full body hockey PPE, the breakdown of individual items' contribution to the GWP impact including the use phase was as follows: pants 14.6%, elbow pads 3.8%, shoulder pads 9.3%, shin guards 9.5%, gloves 5.8%, jersey 22.1%, stick 0.02%, socks 7.3%, puck 3.8%, helmet 15.1%, and the use phase 8.7%. Likewise, for full body football PPE breakdown of individual items' contribution to to total GWP impact including the use phase was as follows: pants 22.0%, shoulder pads 35.3%, gloves 4.0%, jersey 5.6%, socks 3.3%, helmet 18.7%, rubber football 7.7% and the use phase 3.6%. The use phase: monthly washes for one year, added an additional 1.23 kg CO_2 eq. to hockey's GWP and 0.61 kg CO_2 eq. to football's GWP.

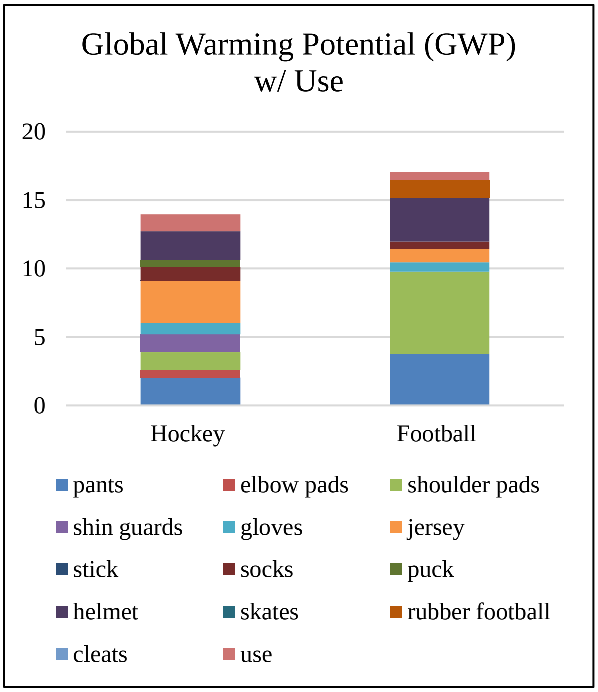

Figure 4. Global Warming Potential for full body Hockey and Football PPE and the use phase of each sport (in kg CO_2 equivalents). The addition of the use phase adds about 1 kg CO_2 eq. to hockey's GWP and 0.61 kg CO_2 eq. to football's GWP.

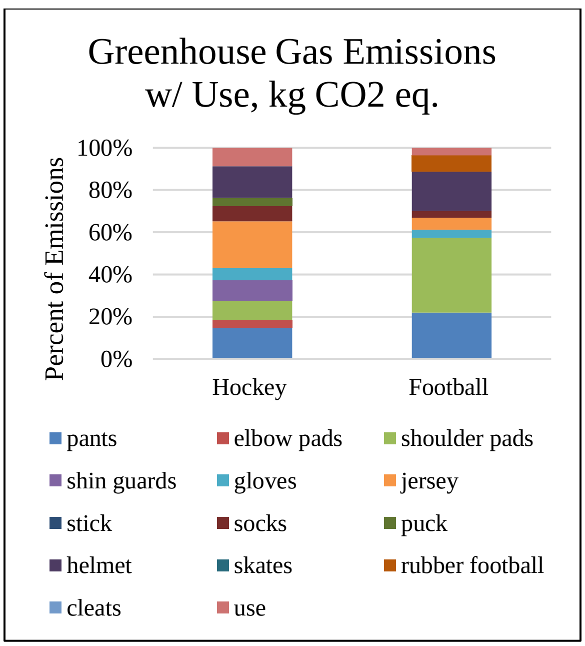

Figure 5. Greenhouse Gas Emissions for each element of Hockey and Football PPE as well as the use phase for each sport as a percentage of each sport's total emissions. With the addition of the use phase, the highest percent of emissions for hockey equipment still came from jersey (100% polyester) production stages. This trend continued for football equipment where shoulder pad production stages had the highest percent of gas emissions.

DISCUSSION

After performing an LCA and comparing our results for children's football and hockey equipment, we found that football had the greatest GWP. This is likely due to the amount of high-density polyethylene plastic (1.861 kg) found in the shoulder pads. These results did not support our hypothesis that hockey equipment would have the greatest GWP. It is possible that the GWP for hockey will increase once footwear: cleats and skates are assessed for environmental impact. The metal found on hockey skates is typically made from steel. A previous LCA found that 1 kg of steel has a GWP of 1.6 kg CO_2 eq. (World Steel Association, 2011). This along with the other materials found in hockey skates will surely increase the overall GWP of hockey equipment. Moreover, it is typical for athletes who play ice hockey regularly (15-20 hours a week) to sharpen their skates on a weekly basis (American Athletic Shoe, 2019).

While footwear was not included in the LCA of youth football and hockey equipment, it is still important to reference potential impacts. In regard to the cleats worn in football, the production of the fabric and plastic elements carry the largest environmental impact while impacts from the use phase are minimal due to the low maintenance of cleats. On the other hand, skates worn in hockey not only have fabric, plastic, and metal elements, but require regular maintenance in the sharpening of the blades. Electricity use from the sharpening of skates would increase GWP of hockey proportional to the amount of time played. This is because the more use the hockey skates get, the more they need to be sharpened and hence the increase in GWP from electricity use.

Furthermore, while previous LCAs on textiles (van der Velden et al., 2014; Steinberger et al., 2009; Nolimal, 2018) found that the use phase carries the largest environmental impact, this was not the case for hockey and football sporting equipment. This is most likely due to the fact that responses to the parent athletic survey reported monthly washings followed by air-drying. Without the electricity usage of a drying machine, the use phase was calculated to be significantly lower than for example, a sweater. Nolimal (2018) determined the use of a sweater to be between that of a T-Shirt and jacket and assumed 28 washes for the lifecycle of a sweater. This produced a GWP of 38.1 kg CO_2 eq. Since the survey was only given to 20 parents whose children currently participate in either hockey or football, it is important to note that the use phase itself is highly variable and depends on user behavior and equipment choices (Beemkumar, 2015). That being said, it is worth surveying a larger number of parents to get a more accurate representation of the use phase of both hockey and football equipment. If the consumer does not dry their equipment, they have cut out the most energy intensive process. Therefore, user behavior has the potential to increase the impact of sport's equipment

Based on my findings, youth football and hockey seem to have a large environmental impact measured in GWP. As children grow, they tend to require new, bigger equipment. This will only add to the overall GWP of the products. Since this is a preliminary study, and is unique to the field, further analysis is still needed before the sporting goods industry can use it to prioritize improvements on their products. With this being said, my findings can still be used to influence consumer behavior. Based on the sample who completed the "Sports and the Environment: Parent Athletic Survey," it is apparent that not drying PPE can reduce the overall impact of the sports gear. Muthu (2015) found that the use phase is the most critical phase in determining environmental impact, and it is responsible for the maximum impacts in the LCA of clothing products. Thus, not drying equipment is sure to reduce the overall impact of the sports gear.

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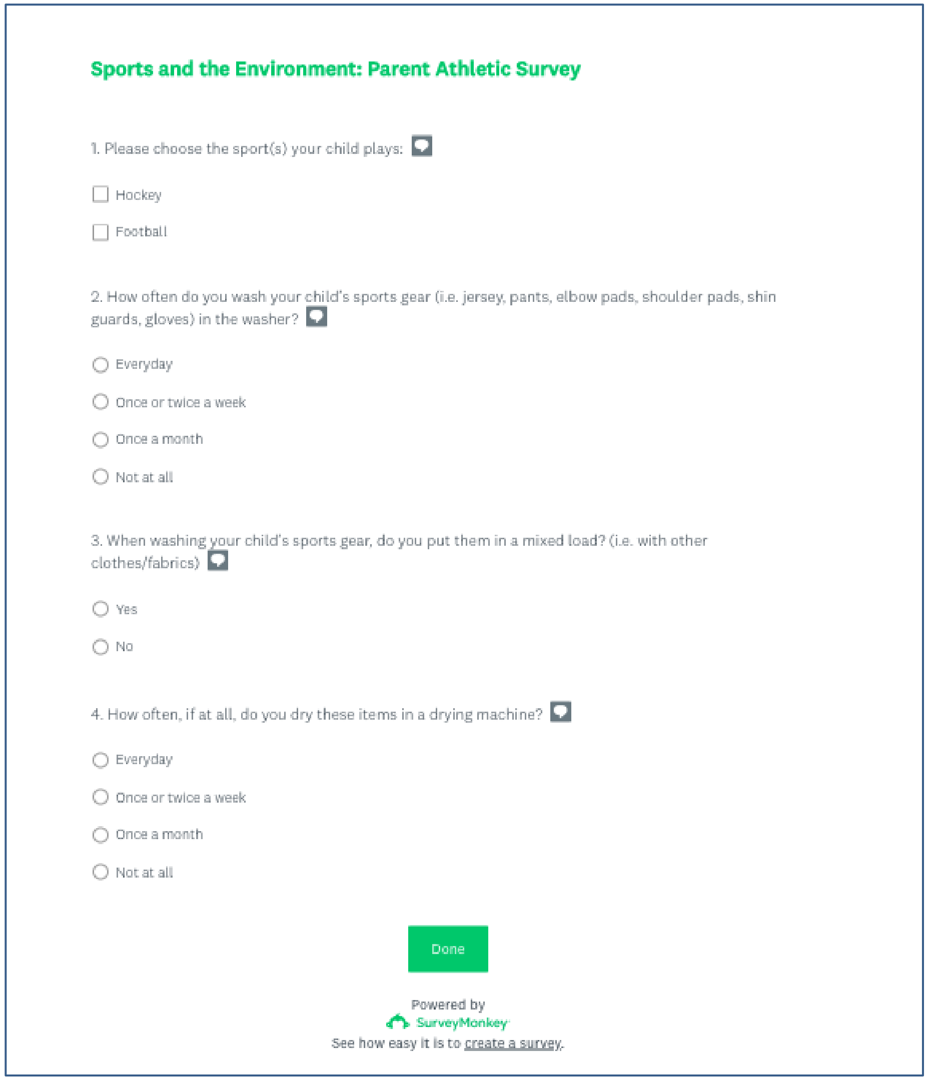
APPENDIX



Sports and the Environment: Parent Athletic Survey

1. Please choose the sport(s) your child plays:

- [ ] Hockey
- [ ] Football

2. How often do you wash your child's sports gear (i.e. jersey, pants, elbow pads, shoulder pads, shin guards, gloves) in the washer?

- Everyday
- Once or twice a week
- Once a month
- Not at all

3. When washing your child's sports gear, do you put them in a mixed load? (i.e. with other clothes/fabrics)

- Yes
- No

4. How often, if at all, do you dry these items in a drying machine?

- Everyday
- Once or twice a week
- Once a month
- Not at all

Done

Powered by SurveyMonkey

See how easy it is to create a survey.

Figure 6. Sports and the Environment: Parent Athletic Survey

Hockey		**Acidification**	**Ecotoxicity**	**Eutrophication**	**Global Warming**
	Units	kg SO2 eq	CTUe	kg N eq	kg CO2 eq
pants		6.35E-03	2.15E+00	2.58E-03	2.04E+00
elbow pads		1.66E-03	5.63E-01	6.75E-04	5.34E-01
shoulder pads		4.04E-03	1.37E+00	1.64E-03	1.30E+00
shin guards		5.31E-03	2.93E+00	2.84E-03	1.32E+00
gloves		1.54E-03	4.11E-02	1.52E-04	8.06E-01
jersey		4.20E-03	9.19E-02	5.06E-04	3.09E+00
stick		1.44E-05	1.04E-02	1.12E-05	2.52E-03
socks		1.38E-03	3.02E-02	1.66E-04	1.01E+00
puck		2.44E-03	1.82E+00	1.29E-03	5.23E-01
helmet		8.03E-03	2.15E+01	6.58E-03	2.10E+00
skates		N/A	N/A	N/A	N/A
use		2.34E-01	5.54E-01	8.95E-05	1.22E+00
Total		2.69E-01	3.10E+01	1.65E-02	1.40E+01

Table 1. The environmental impacts, as described by four of the ten TRACI impact categories, are displayed for component material production of each item in the full body personal protective equipment uniform for ice hockey. Total impacts of the sports equipment are also displayed in the bottom row.

Football		**Acidification**	**Ecotoxicity**	**Eutrophication**	**Global Warming**
	Units	kg SO2 eq	CTUe	kg N eq	kg CO2 eq
jersey		1.54E-03	1.80E-01	3.20E-04	9.62E-01
gloves		1.45E-03	3.65E-01	4.83E-04	6.76E-01
socks		1.65E-03	4.45E-01	7.33E-04	5.62E-01
pants		5.11E-03	1.12E-01	6.15E-04	3.75E+00
rubber football		6.09E-03	4.56E+00	3.23E-03	1.31E+00
helmet		9.48E-03	1.66E+00	1.01E-03	3.17E+00
shoulder pads		1.79E-02	2.87E+00	1.83E-03	6.03E+00
cleats		N/A	N/A	N/A	N/A
use		1.17E-01	2.77E-01	4.48E-05	6.10E-01
Total		1.60E-01	1.05E+01	8.27E-03	1.71E+01

Table 2. The environmental impacts, as described by four of the ten TRACI impact categories, are displayed for component material production of each item in the full body personal protective equipment uniform for tackle football. Total impacts of the sports equipment are also displayed in the bottom row.

item	total mass (g)	material	mass (g)	material from database	database
pants	440	polyethylene foam	220	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
pants	440	polyurethane foam	220	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
elbow pads	115	polyethylene foam	57.5	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
elbow pads	115	polyurethane foam	57.5	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
shoulder pads	280	polyethylene foam	140	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
shoulder pads	280	polyurethane foam	140	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
shin guards	365	polyethylene vinyl acetate	182.5	ethylene vinyl acetate copolymer production | ethylene vinyl acetate copolymer | cut-off, U	ecoinvent
shin guards	365	polyurethane foam	182.5	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	185	polypropylene foam	92.5	Polypropylene (PP) - fabric, production mix, at plant, technology mix, PP	ecoinvent
gloves	185	polyethylene foam	92.5	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
jersey	436	polyester	436	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
stick	90	carbon fiber	90	graphite production | graphite | cut-off, U	ecoinvent
socks	143	polyester	143	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
puck	170	black rubber	170	synthetic rubber production | synthetic rubber | cut-off, U	ecoinvent
helmet	814	polyethylene	25.8	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
helmet	814	polypropylene	10.2	polypropylene (PP) - fabric, production mix, at plant, technology mix, PP	ecoinvent
helmet	814	polytherimide	25.4	Polyetherimide granulate (PEI), production mix, at plant, technology mix, PEI	gabi
helmet	814	silicone	18.4	silicone product production | silicone product | cut-off, U	ecoinvent
helmet	814	steel	24.2	steel production, chromium steel 18/8, hot rolled | steel, chromium steel 18/8, hot rolled | cut-off, U	ecoinvent
helmet	814	polyethylene	295	polyethylene production, high density, granulate | polyethylene, high density, granulate | cut-off, U	ecoinvent
helmet	814	carbon steel	255	steel production, converter, low-alloyed | steel, low-alloyed | cut-off, U	ecoinvent
helmet	814	eva	160	ethylene vinyl acetate copolymer production | ethylene vinyl acetate copolymer | cut-off, U	ecoinvent

Table 3. Materials from openLCA databases and masses used to calculate environmental impacts of full body hockey PPE.

item	**Total mass (g)**	**material**	**mass (g)**	**material from database**	**database**
jersey	140	92% polyester	64.4	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
jersey	140	8% spandex	5.6	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
jersey	140	85% polyester	59.5	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
jersey	140	15% spandex	10.5	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	75% polyester	26.25	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
gloves	105	20% silicone	7	silicone product production | silicone product | cut-off, U	ecoinvent
gloves	105	5% spandex	1.75	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	57% polyester	19.95	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
gloves	105	35% polyurethane	12.27	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	5% spandex	1.75	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	3% eva	1.05	ethylene vinyl acetate copolymer production | ethylene vinyl acetate copolymer | cut-off, U	ecoinvent
gloves	105	67% polyester	23.45	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
gloves	105	14% polyurethane	4.9	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	11% spandex	3.85	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
gloves	105	8% nylon	2.8	glass fibre reinforced plastic production, polyamide, injection molded |cut-off, U	ecoinvent
gloves	105	nylon: spinning	2.8	Jute hessain net, single route, at plant, jute cultivation, spinning and weaving, 576 g/m2	gabi
socks	70	58% polyester	40.6	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
socks	70	31% nylon	21.7	glass fibre reinforced plastic production, polyamide, injection molded | cut-off, U	ecoinvent
socks	105	nylon: spinning	21.7	Jute hessain net, single route, at plant, jute cultivation, spinning and weaving, 576 g/m2	gabi
socks	70	6% cotton	4.2	cotton production | cotton fibre | cut-off, U	ecoinvent
socks	70	5% spandex	3.5	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
pants	530	100% polyester	530	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
rubber	425	rubber	425	synthetic rubber production | synthetic rubber | cut-off, U	ecoinvent
helmet	568.9	polyethylene	70	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
helmet	568.9	polyethylene	1.3	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
helmet	568.9	polypropylene	2.9	Polypropylene (PP) - fabric, production mix, at plant, technology mix, PP	ecoinvent
helmet	568.9	yarn	4.9	textile production, knit cotton, yarn dyed | sodium sulfate, anhydrite | cut-off, U	ecoinvent
helmet	568.9	polyethylene	4.8	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
helmet	568.9	polycarbonate	425	polycarbonate production | polycarbonate | cut-off, U	ecoinvent

shoulder pads	2449.4	polyester	135	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
shoulder pads	2449.4	high density polyethylene	1861	polyethylene production, high density, granulate | polyethylene, high density, granulate | cut-off, U	ecoinvent
shoulder pads	2449.4	polyester	3.8	Polyester (PET) fabric, production mix, at plant, technology mix, PET	ecoinvent
shoulder pads	2449.4	nylon	3.8	glass fibre reinforced plastic production, polyamide, injection molded | cut-off, U	ecoinvent
shoulder pads	2449.4	nylon: spinning	3.8	Jute hessain net, single route, at plant, jute cultivation, spinning and weaving, 576 g/m2	gabi
shoulder pads	2449.4	yarn	77.8	textile production, knit cotton, yarn dyed | sodium sulfate, anhydrite | cut-off, U	ecoinvent
shoulder pads	2499.4	polyurethane	6	polyurethane production, flexible foam | polyurethane, flexible foam | cut-off, U	ecoinvent
shoulder pads	2499.4	nylon: spinning	6	Jute hessain net, single route, at plant, jute cultivation, spinning and weaving, 576 g/m2	gabi
shoulder pads	2449.4	nylon	6	glass fibre reinforced plastic production, polyamide, injection molded | cut-off, U	ecoinvent
shoulder pads	2449.4	polyethylene	26	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent
shoulder pads	2449.4	latex	150	latex production | latex | cut-off, U	ecoinvent
shoulder pads	2449.4	polyethylene	180	Polyethylene (HDPE/PE-HD) - fabric, production mix, at plant, technology mix, HDPE/PE-HD	ecoinvent

Table 4. Materials from openLCA databases and masses used to calculate environmental impacts of full body football PPE.